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TEACHER'S RESOURCE BOOK

NONRENEWABLE SOURCES OF ENERGY

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SEEDS

The Energy Literacy Series

NONRENEWABLE SOURCES OF ENERGY

TEACHER'S RESOURCE BOOK

SRA

SCIENCE RESEARCH ASSOCIATES (CANADA) LIMITED
Toronto, Montreal, Chicago, Palo Alto, Sydney, Henley-on-Thames

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COVER DESIGN: Dykeman, Tabor & Reeves-Stevens, Ltd.

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ACKNOWLEDGMENTS

Every effort has been made to identify and credit appropriately the sources of all copyright material used in this book. Any information concerning perceived errors or omissions will be appreciated, and the correct source acknowledged in subsequent editions.

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Printing History
10 9 8 7 6 5 4 3 2 1 91 90 89 88 87 86 85 84 83 82

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PREFACE

"Because our society is geared to living from day to day, it is difficult to recognize the long-term significance of events that are happening now. Even on major issues, we expect immediate action from our leaders, and we generally limit our own participation to reading the headlines.

But, in the next twenty to fifty years, the world will undergo massive changes in its supply and use of energy. In order to cope, we will have to alter lifestyles and expectations. We must recognize, too, that the greatest changes will occur during our children's lifetimes, and beyond ours. We will be shirking our responsibility unless we do everything possible to prepare the next generation for these social changes.

Society must stop forming its opinions about energy from headlines only. We must learn, and teach, the facts and encourage the most careful analysis of the issues. Emotionalism can only deter society from effective action."

Marshall Williams

Marshall Williams is a director and past president of SEEDS, the nonprofit foundation he was instrumental in establishing in May 1976. The acronym SEEDS identifies both the organization—Society, Environment & Energy Development Studies Foundation—and its offspring, the curriculum project now reaching published form.

From its beginning, SEEDS has worked toward its primary goal—to encourage the development of an "energy-literate" society, a society concerned about and committed to the wise use of energy.

The first task undertaken was the coordination of available human and material resources for energy and environment education, with the objective of developing twelve levels of curriculum materials for elementary and secondary school use. To accomplish this task, sixty educators, teams of 5 working at each level, immersed themselves in the wide range of materials made available to them, sifting and organizing the topics and issues into meaningful units of classwork appropriate to students' level of growth and understanding. Then, 150 teachers, with prior in-service training, tried out the study modules with more than 4000 students during the 1978-79 school year. Concurrently, a formal evaluation of these pilot units was undertaken by a team of professors of education. This class-testing and evaluation, combined with information and reviews provided by educators and personnel from energy-related industries and government bodies, provided guidelines for additional teams of teachers who then revised the materials.

Throughout, with the involvement of educators, environmentalists, business people, industry consultants, and government representatives, we have tried to achieve the presentation of balanced and objective educational modules that will help young people develop informed views of energy and the environment and act on them.

Our first years have been challenging, exciting, and rewarding. While there are many individuals to whom we extend our appreciation for helping to maintain this sense of purpose, one individual stands out as deserving of special thanks. Dr. Marshall Williams has been a constant source of leadership, encouragement, and most of all, vision.

Robert Westbury
Executive Director
SEEDS Foundation

INTRODUCTION

The SEEDS Curriculum Project, produced and published by SRA, provides both student and teacher materials for a four- to six-week unit of study on energy-related concepts. It is designed to help teachers incorporate this topical material into their regular science/social studies curricula by providing a "guided discovery" approach suited to the students' level of growth and understanding.

Information on both the SEEDS Foundation and the history of the SEEDS Curriculum Project is given in the Preface. This Introduction outlines the organization of the curriculum materials.

The components for this Level include a Teacher's Resource Book with Professional Reference Guide and a 64-page Student Book.

The Teacher's Resource Book provides information and guidelines, organized in a sequence of chapters for presenting the topics and carrying out the experiments, discussions, and other investigations. A description of the key elements of each chapter follows.

STRUCTURE OF CHAPTERS

Each chapter begins with a summary of practical details, set out to assist the teacher in planning and preparation. Following this summary appear some or all of the sections entitled Teacher Background, Core, and Extension(s).

Summary ***Objectives*** The knowledge and process skill objectives appear at the beginning of each chapter.

Time Since the time allotted to science and social studies within the curriculum varies widely from district to district, we have indicated the probable time for each activity or experiment. The Core program will require four to six weeks, depending on how often you schedule science and social studies; the Extensions are not included in this estimate. Because of the nature of the topics and experiments, some activities may take longer than the usual time you allot to a lesson.

Vocabulary One aspect of "energy literacy" is the acquistion of the vocabulary with which to discuss concepts, topics, and issues. Of course, comprehension of the concepts is the ultimate goal, but the chapters themselves are designed to develop that comprehension.

The vocabulary lists are provided for your information and use at your discretion. It is preferable to provide a "handle" or name for a concept when the students themselves request it, having found new words necessary to describe the results of their experiments or the progress of their activities. However, the nature of the material sometimes requires that these words or definitions be introduced by the teacher. The vocabulary for each chapter is stated at the beginning of each chapter. The lists contain those words that the students will encounter in their books or on the Exercise Sheets. The main reference for placing words in the list has been science vocabulary at the grade 7-9 level being used in core science curricula. Other words not in this text but required by the nature of the program are, of course, included.

Upon seeing a vocabulary word, students may look it up in a dictionary or put the word in a notebook to be asked about in class. Text context, labelled diagrams, captions, and questions on Exercise Sheets reinforce vocabulary.

Materials The items listed include other components for the level whether for student or teacher use. Special materials, not usually found in classrooms, are also listed.

Teacher Background Where a major or new concept is introduced, some background information is provided to reduce the need for teacher preparation. It usually takes the form of a brief summary of the basic scientific or technical concepts developed in the chapter. This section does contain more information than that given in the Student Books.

Core This section provides a suggested procedure for the chapter—whether it's a teacher presentation, an experiment, or a discussion—to achieve the stated objectives. Built into the procedure are suggestions for the appropriate introduction or use of the other components noted under the heading, Materials.

Activities These are simple hands-on investigations of some of the basic concepts studied in this unit. They may be demonstrated by the teacher or carried out by the whole class. All materials are listed and should be readily available. Typical student responses are provided where useful.

Extensions This section provides a brief explanation or suggestion for one or more activities that will further develop the sub-topic and related science or social studies skills.

Exercise Sheets Grouped at the end of this Teacher's Resource Book are the Exercise Sheets which are designed to be used as black-line masters. On behalf of SEEDS Foundation, the copyright holder, SRA grants you, the teacher, the right to reproduce the Exercise Sheets for classroom use. They are numbered sequentially and include a key to the chapter number and level title.

Student Book The Student Book serves as a base of reference for the major topic presented in the level. It provides a focus of interest for some group or class discussions, and guidelines for experiments or activities. The illustrations, whether photographic or artwork, have been selected to help students visualize and comprehend the more technical, complex, or unfamiliar elements of their study. A glossary of the vocabulary listed in the Teacher's Resource Book has been included at the back of the Student Book. Italics are used within the Student Book to emphasize safety precautions and procedures.

Energy Literacy Objectives

The objectives, stated in terms of learning outcomes expected for the students, draw on energy-related concepts from the social sciences, the natural sciences, and the physical sciences.

CHAPTER	KNOWLEDGE	PROCESS SKILLS
1 *Nonrenewable Sources of Energy*	• define energy by some of its many forms and uses • explain how the sun is the source of most of the earth's energy • relate activity and motion to energy • explain why fuel sources used in Canada were first wood, then coal, then petroleum • fit the present widespread use of petroleum for heating and transportation into a historical time frame	• use a scale to register variations in opinions • extract data from a line graph
2 *Energy from Coal*	• relate the process by which the sun's energy was converted into the fossil fuel we know as coal • explain why coal is called a fossil fuel • explain why not all types of coal have the same composition and how this affects fuel quality	• compare observations with predictions • gather data from a circle graph • construct plaster of Paris casts of impressions • identify different grades of coal by property
3 *Extracting and Processing Coal*	• explain how coal lying near the surface is mined • explain how coal lying far below the surface is mined • list some of the hazards of underground mining • explain what happens to raw coal to prepare it for the buyer • locate the coal resources in Canada • explain the effect strip mining can have on the environment • explain the effect underground mining can have on the environment • explain how a planned reclamation can offset the worst effects of strip mining	• interpret a diagram • calculate large numbers with a calculator • calculate percentages using given information
4 *Using Energy from Coal*	• account for the changes in the use of coal from 1950 to 1980 • explain how coal is used in the production of steel and electricity • list some of the many by-products from the destructive distillation of coal • name the harmful by-products from the burning of coal and other fossil fuels • explain how acid rain is formed • test the known effects of acid rain • list some of the efforts being considered by industry and government to overcome the problem of acid rain • identify the regions in North America most likely to show the effects of acid rain	• compare bar graphs • produce coal gas, coke, and coal tar in a laboratory activity • apply discovered knowledge • identify solutions as acids or bases • neutralize an acid solution • carry out an experiment by stating the purpose, identifying and controlling the variables, making and recording observations, and stating a conclusion
5 *Energy from Petroleum*	• explain the theory of the formation of petroleum • explain how petroleum deposits are located by seismic survey	• calculate the distance across a body of water using seismic principles
6 *Extracting and Processing Petroleum*	• explain how petroleum deposits are reached and how petroleum is brought to the surface • explain how petroleum deposits that lie under the ocean are reached • describe the nature and extent of the oil-sands deposits in Alberta • describe the processes used to mine the oil sands • explain how synthetic crude oil is extracted from the oil sands • investigate methods of transporting oil from offshore-drilling rigs • explain how oil is transported from the well to the refinery over land and across water	• construct a model oil well • draw a scale diagram • construct a model of oil-sands extraction • apply the principles learned from models to real-life situations • observe the principle of distillation • interpret results

CHAPTER	KNOWLEDGE	PROCESS SKILLS
6 *(continued)*	• explain what distillation means • explain how the principle of distillation can be used to separate liquids with varying condensation temperatures	
7 ***Using Energy from Petroleum***	• recognize that the refinery turns crude-oil fractions from the fractionating tower into more than 1000 different products • recognize that natural gas will provide heat, fuel, and the raw material for products in the petrochemical industry • explain what effects oil-sands extraction has on the environment • explain why oil is spilled on land or on water • explain why oil spills can be damaging to the land and sea environment • explain what eventually happens to organic materials, such as oil	• apply discovered knowledge • measure a circle graph
8 ***Energy from Uranium***	• recognize how uranium deposits are located • explain the difference between uranium and stable materials	• calculate the amount of radiation to which an individual is exposed
9 ***Extracting, Processing, and Using Energy from Uranium***	• tell the story of the uranium cycle from exploration to nuclear reactor • describe an atom • give a simple explanation of fission • explain how electricity can be produced from uranium • list the advantages of producing electricity by nuclear reactor, and the disadvantages • list some of the beneficial ways radioactivity is being used	• construct an atomic model • apply discovered knowledge
10 ***The Future of Nonrenewable Energy Sources***	• organize the facts learned about the extraction and use of coal • predict how the use of coal in Canada may change in the next ten years • describe what effects those changes in the use of coal will have • relate the use of petroleum as a source of energy to the larger picture of human history • discuss alternatives to solve the problem of petroleum shortages • relate the use of uranium as a source of energy to the larger picture of human history • recognize new ways in which uranium could be used • explain the benefits, and the environmental effects, of coal, oil, natural gas, and uranium	• apply discovered knowledge • interpret statistical information • interpret bar graphs • interpret a time line • interpret a circle graph • create a new graph • present information in a way that will persuade adults to change their attitude on a specific topic

Chapter 1

Nonrenewable Sources of Energy

OBJECTIVES

Knowledge

- **define energy by some of its many forms and uses**
- **explain how the sun is the source of most of the earth's energy**
- **relate activity and motion to energy**
- **explain why fuel sources used in Canada were first wood, then coal, then petroleum**
- **fit the present widespread use of petroleum for heating and transportation into a historical time frame**

Process Skills

- **use a scale to register variations in opinions**
- **extract data from a line graph**

Vocabulary

atmosphere, convert, kerosene, petroleum, prediction, reserve, solar energy, uranium

Materials

Student Materials—see Student Book page 8
Exercise Sheets 1, 2

TEACHER BACKGROUND

It is commonly accepted that the sun is the source of most of the earth's energy. The life-giving role of the sun in the growth of plants and animals, the fossilization of early plant forms into fossil fuels, the production of wind energy from the movement of air in response to unequal heating of the earth's surface by the sun, and the water cycle and the resulting movement of water that gives energy for electrical power, are all dependent on the sun's energy.

CORE

Student Book pages 5-6

Student definitions of energy should express the idea that energy can do things. Students sometimes confuse energy, force, and power. Force is a push or pull, and it takes energy to create a force. Power measures how fast energy is doing things.

A definition that accommodates all of the illustrations on Student Book page 5 is the goal. The illustrations on Student Book page 5 could also be used to discuss the different forms energy can take and the diagram on Student Book page 6 to review the importance of solar energy for life on earth.

You may also wish to review the concepts of "renewable" and "nonrenewable" energy sources. Exercise Sheet 1 may be used in this review.

Exercise Sheet 1

The line that divides renewable resources from nonrenewable resources is clear for most sources of energy, but not so clear for others. Solar energy, for example, on any time scale that makes sense is a renewable energy source. In fact, the sun is slowly consuming itself and will eventually burn out. This point may be raised by students.

Exercise Sheet 2

Before assigning students this energy-opinion survey, give them practice in using a scale to record opinion by posing a question unrelated to the energy topic, such as "Cats make better pets than dogs."

After students complete the energy-opinion surveys, you could collect the surveys and assign them again at the conclusion of the unit or later in the school year. Students may be interested in comparing their first and subsequent opinions.

A graphing exercise may also be undertaken. A bar graph can be made to record the variation of opinion in the class by graphing the numbers of pupils for each point in the opinion scale. A separate graph can be made for each question, and

pupils will readily see which of the opinion statements represents the greatest agreement.

Student Book pages 6-7

Have students read the text and answer the first three questions posed in the Student Book. Answers to question 3 on Student Book page 7 could be charted. When all students have finished, have them share their answers in a class discussion.

Then, before students complete the remaining two questions, have them examine the graph on Student Book page 6. The history of the four fuels in Canada can be told by comparing the graphs for each fuel with the dateline. Note that electricity cannot be classed with wood, coal, oil, and natural gas because electricity for heating may be produced from falling water in a hydroelectric station, or by burning coal, oil, or gas in a thermal-electric station, or by nuclear reaction in a nuclear-electric station.

The students should conclude that Canada relies largely on nonrenewable sources of energy. Discuss the significance of the information. Students could consider the questions: If energy reserves are large, are we in a different situation than if the reserves are small? Does it matter if the energy reserves are in this country, or in some other country?

Student Book page 8

Activity (Set-up—5 min; Duration—15 min). This activity can be used to demonstrate to students why new energy sources become popular. They will be able to see that kerosene lamp light is preferable to candlelight for most activities, and that electric light is preferable to both in most instances.

Because kerosene is highly flammable, you should perform this activity as a demonstration.

Answers

Type of Light	*Quality of Light*
candle	dull and flickering
kerosene lamp	brighter than a candle, but still dull, lighting only a small area
electric lightbulb	much brighter and constant, lighting a larger area

When the class has finished writing its observations, you might like to have the students discuss the differences in safety and convenience that exist among the three types of light. For example, a candle provides a soft, flickering light that is of relatively short duration. Any flammable object near a candle might be set alight. Kerosene lamps provide a clear, steady light, but they hold relatively little fuel and the glass chimneys become dirty very quickly. Thus kerosene lamps must be filled and cleaned daily.

EXTENSIONS

Students may wish to sample and compare the opinions of members of their families by using the opinion survey on Exercise Sheet 2.

Social Awareness Students may wish to conduct several interviews with elderly people on life style before electric lights and oil or gas heating. Tape recordings may be an effective method of interviewing. If interviews are impossible, have some students play the part of the interviewer and interviewee. They might like to use questions similar to the following:

- How did electric lights improve your life?
- How did you guard against fire when you used kerosene lamps?
- Did kerosene lamps use much fuel?
- What special care did you have to give the lamps?

Chapter 2

Energy from Coal

OBJECTIVES

Knowledge

- **relate the process by which the sun's energy was converted into the fossil fuel we know as coal**
- **explain why coal is called a fossil fuel**
- **explain why not all types of coal have the same composition and how this affects fuel quality**

Process Skills

- **compare observations with predictions**
- **gather data from a circle graph**
- **construct plaster of Paris casts of impressions**
- **identify different grades of coal by property**

Vocabulary

anthracite, bituminous, carbon, Carboniferous Period, crucible, decay, deposits, element, fossil, gold, hydrocarbon, hydrogen, iron, jet, lignite, organic, oxygen, platinum, residue, sandstone, seam, sediment, sedimentation, shale, sub-bituminous, sulfur

Materials

Student Materials—see Student Book pages 10, 11, 12, 13

TEACHER BACKGROUND

The age of the earth is an informed speculation by the sciences of astronomy, physics, chemistry, and geology. One current guess is four and one-half billion years.

It is believed that coal was formed about three hundred million years ago. This era is called the Carboniferous Period. Often, as the layers of vegetable and animal sediments that eventually became coal were laid down, some of these organic materials were preserved as fossils.

There are three principal ways in which organic material is preserved as fossils. Sometimes, some or all of the original animal or plant material is preserved. For example, insects may be preserved whole in sticky tree resin which becomes amber. The flesh of vanished species of elephants has been recovered from the frozen soil of areas such as Siberia. Bones, teeth, and shells also fall into this class of fossils. In other cases, plant and animal remains that become embedded in mud may leave an impression. As the organic material disappears, a mold is left of the original form. Sometimes the mold fills with mud which hardens into rock in the form of the original plant or animal. Under the right conditions, a chemical process called petrifaction can occur, in which the actual atoms of the organic original are replaced with atoms of some mineral material, such as calcium carbonate or silica. Fossilized wood can show not only yearly growth rings, but minute details of the bark of the tree. Microscopic examination reveals even the cell structure of the original duplicated in stone. Fossils in coal seams are made in this way.

Coal was the fuel most commonly used for space heating until the late 1940s, when large oil and gas discoveries in Alberta influenced Canadians toward a fairly rapid changeover to furnace oil and gas. From supplying about 80% of the country's primary energy needs in 1900, coal has dropped to supplying only about 9%.

Coal as a fuel has two main uses. Thermal coal is coal which is suitable for heating purposes. This type of coal is widely used in some areas of the country to provide steam for electricity-generating steam turbines. Metallurgical coal, or coking coal, has qualities needed in the production of steel.

Coal is graded into four ranks. The better quality coals, anthracite and bituminous, are mixed to make coking coal. If available, the less desirable, and cheaper, sub-bituminous is usually used as thermal coal. Lignite, with its high moisture content, disintegrates in air and is subject to spontaneous combustion. When other coals are too expensive to purchase and transport, lignite is used as a thermal coal.

CORE

Student Book page 9

Assist students in relating the time span of the history of humankind to the Carboniferous Period when coal deposits were laid down. It may help students to understand the immense span of time from the Carboniferous Period to the present if the history of the world is compressed into a single year.

The Age of the Earth Compressed into One Year

Jan 1	The Earth is formed
Feb	|
Mar	and
Apr	life
May	begins
June	|
July	|
Aug	|
Sept	|
Oct	|
Nov 20	Invertebrates appear First abundant fossils
Dec 7	Carboniferous Period
15	Dinosaurs
27	Flowering Plants
31	*16 00* A human-like creature leaves footprints in volcanic ash in Africa. The footprints become fossilized.
31	*23 59* Recorded history begins one minute before midnight. *23 59 47* Thirteen seconds before midnight Christ is born. Most North Americans number their calendar from this time. *23 59 59* Within this last second much of what we call science and technology is discovered: electricity, airplanes, automobiles, trains, photography, radio, television, and so on.

Student Book page 10

Activity (Set-up—10 min; Duration—24 h). It is not easy for students to relate their memories of the mosses and ferns of the woods to a lump of the black rock we call coal. The effects of great heat and pressure over very long periods of time may be easier for students to imagine when they are applied to mud and sand. You could begin the discussion with this activity.

Students are first asked to predict what will happen if they stir the ingredients in water and allow them to settle. After sedimentation has occurred, you might like to ask questions such as:

- Why did the particles settle in layers?
- Which particles settled first? Why?
- Why was sedimentation more apparent in some jars than in others?

If samples of shale, sandstone, and limestone are available, ask the students to identify the layers in their jars that might become those sedimentary rocks under forces of pressure and heat.

Activity (Set-up—10 min; Duration—15 min). This activity may be undertaken by an interested student or students. Note that large chunks of cannel coal, available in most communities, are suitable for this activity. While fossils cannot readily be found in all coal samples, the layering of coal does give students an idea of how coal was formed.

Student Book page 11

Activity (Set-up—15 min; Duration—20 min). The specimens used for the

making of the impressions in this activity are of a comparable nature to fossils which were made in this manner. Ferns, leaves, and shellfish made fossils through leaving impressions into which rock became molded.

Student Book page 12

Activity (Set-up—15 min; Duration—20 min). This activity will help to demonstrate the wide availability of carbon in nature. The students, with help, should be able to compare the sooty substance derived from a candle flame to the carbon formed when aspirins are heated and to the carbon formed when wood is burned. Have them chart their observations.

If you wish, you could perform a demonstration to show how carbon occurs in the most unexpected forms such as sugar. As this demonstration uses sulfuric acid, it is suggested that you perform the demonstration with the students acting as observers only.

1. Discuss with the students the fact that sulfuric acid has the capacity to extract water from substances it touches. (This action is called dehydration.)
2. Fill a beaker one-quarter full with sugar.
3. Add an equal amount of concentrated sulfuric acid. The dehydrating action of the sulfuric acid will remove the water from the sugar.
4. A frothy black column of carbon will be produced.

Student Book page 12

Refer students to the circle graphs, drawing attention to the high-percentage figure for the presence of carbon in the human body. Ask pupils to try to explain why carbon makes up a comparatively small part of the circle graph for the earth's composition.

Student Book page 13

Activity (Set-up—10 min; Duration—25 min). Combustion of coal produces carbon monoxide, so adequate ventilation is necessary when coal is burned in the classroom. If you are unable to obtain samples of different types of coal, students may be asked to do this activity as a research project—to obtain the information in small groups and give class reports.

Answers

OBSERVATION Anthracite started to burn first.
Bituminous coal was the second.

Anthracite coal gave off heat for the longest period of time.

Lignite coal gave off heat for the shortest period of time.

CONCLUSION You can feel the heat that burning coal gives off.

Anthracite coal has the greatest heat value. It burns longest and gives off the greater amount of heat.

The harder the coal, the greater the heat energy produced.

Have students chart their observations. Referring to their charts, they should be able to reach the same conclusions as did homeowners of fifty years ago—that anthracite burns hottest and longest, and makes the best fuel. Ask the students which grade of coal they would expect to be found least often, and why (anthracite because the greatest heat-pressure-time is needed to create it). Anthracite, needless to say, is the most expensive grade of coal.

EXTENSION

Students may be familiar with peat, organic material that is still in the first stages of the process that turns plants into coal. Peat is dug in various parts of Canada. The pros and cons of using peat as a fuel in Canada could be assigned to some students as a topic for further research.

Chapter 3

Extracting and Processing Coal

OBJECTIVES

Knowledge

- **explain how coal lying near the surface is mined**
- **explain how coal lying far below the surface is mined**
- **list some of the hazards of underground mining**
- **explain what happens to raw coal to prepare it for the buyer**
- **locate the coal resources in Canada**
- **explain the effect strip mining can have on the environment**
- **explain the effect underground mining can have on the environment**
- **explain how a planned reclamation can offset the worst effects of strip mining**

Process Skills

- **interpret a diagram**
- **calculate large numbers with a calculator**
- **calculate percentages using given information**

Vocabulary

black water, carbon dioxide, chokedamp, collapse, dragline, element, explosion, firedamp, horizontal, longwall mining, methane, overburden, reclaim, refuse, residue, soil profile, spoil, subsoil, topsoil, trench, vertical, water table

Materials

Student Materials—see Student Book page 18
Exercise Sheets 3, 4, 5

TEACHER BACKGROUND

Canada has between one and two per cent of the world's resources of coal, an amount that is more than adequate for our foreseeable needs well into the future. There are estimated reserves of four and two-thirds billion tonnes of thermal coal and one and one-quarter billion tonnes of metallurgical coal which can be mined profitably with present technology. Another four hundred and seventy-five billion tonnes will be available for the future as developments in technology make it feasible and profitable to mine deposits in the far north and in very mountainous areas.

Approximately 85% of the coal in this country lies in shallow deposits that can be worked with strip-mining techniques. These deposits are in the Rockies, on the Prairies, and in New Brunswick. Except in some surface mines in the Rockies, where deposits may be in rugged areas overlain by rocky overburden, the coal can be mined at reasonable cost.

All of the deposits in Nova Scotia and some in British Columbia and Alberta lie far below the surface and are reached only by underground shafts and tunnels that are dug at great expense.

The transportation costs of moving coal by rail and ship are usually greater than the cost of production. They are, therefore, a major consideration in the feasibility of any mine operation.

The increased demand for coal that has occurred since the mid-1970s has meant that some mines, which were operating at a low level of production, are once again profitable. Production has increased for this reason in Cape Breton Island.

Coal is a dirty fuel. Mining for it creates dust and the miners breathe it in. If the ventilation system bringing fresh air into the mine is not adequate, miners can get the disease called "black lung." It is a serious threat to health in the coal mine. Of the 4500 underground coal miners in Canada, 700 have been made unfit for work by "black lung" and another 700 have the disease in various lesser stages.

"Black lung" is not the only hazard in the coal mine. Miners can be asphyxiated by carbon dioxide. Explosive methane gas is also released by mining operations. An "explosion" is really a very rapid burning that happens in a confined space. If enough tiny particles of coal dust are in the air, they can burn in a violent explosion. Sometimes water is sprayed to keep the dust down. Good ventilation in the mine helps to prevent both methane and coal dust explosions.

A constant supply of cool air is needed for another reason. As the mine shaft is sunk deeper into the earth, the temperature increases. For every 50 m below the surface, the temperature increases about 1°C. At great depths, it is so hot that the miners cannot work efficiently, so large volumes of fresh air are brought down from the surface. In many mines, the amount of air pumped through the mine every day has a greater mass than the coal sent to the top during the day.

In some mines, pumps are also needed to move water to the surface. If the coal seam lies below an underground stream, drainage into the mine is a problem. The pumps may work without stopping to keep the mine dry enough to work in. Under such conditions, the possibility of a sudden flood is always present.

Another hazard that miners must guard against is cave-in. As the coal is removed from the seam, the roof is held up only by the sides of the tunnel. Wooden timbers or steel pillars must be continually set up to help support the roof.

Sometimes valuable coal seams may be less than one metre thick. In this case, it is necessary to remove rock around the seams so that miners and machines have enough space. Digging out the rock is dusty work. Water is sprayed to keep the dust down. The miners wear masks to prevent silicosis, a lung disease caused by inhaling tiny particles of rock.

Concern about damage to and disfigurement of the landscape has increased in Canada with the growth of population, greater accessibility of the public to areas distant from population centers, and a growing public opinion that environmental damage should be kept to a minimum.

Strip mining for coal takes place in New Brunswick, in the Rockies, and on the Prairies. Most strip-mining operations uncover the coal by simply stripping away the overlying layers of soil and rock, but in the Rockies, the seams of coal lie below rocky beds that must be blasted away.

Strip mining and underground mining both have an impact on the physical environment. Surface-mining areas can be landscaped by backfilling and vegetation can sometimes be restored. Reclamation success varies with the slope of the land and the acid content of the soil. Soils high in sulfide make reclamation difficult. Costs also vary, but 4% of the cost of coal production is a rough estimate of the money needed to restore land after strip mining. Water courses in strip-mined areas can become acidic from the formation of sulfuric acid caused by the decomposition of pyrite, or iron sulfide, common in coal deposits. Lime, limestone, or caustic soda may be added to the fill to counteract the acidity.

Underground coal-mining operations can also damage the environment. Mine shafts can collapse and cause soil subsidence. "Black water" refuse from coal washing can contaminate water courses. Gases formed in the unsightly waste piles can ignite spontaneously and pollute the air, as well as cause water contamination.

A 1979 United Nations energy report states that in the Rhineland in Germany reclamation efforts have been so successful that hay and grain can be grown on land restored less than five years before.

CORE

Student Book pages 14-16

Have the students read about strip mining and explain the operation in their own words. The extent of disturbance to the landscape caused by strip mining may attract the students' attention. The topic will be dealt with later in this chapter.

Have the students read about underground mining. The illustrations and diagrams should make the details of the operation clear. Underground mining is one of the more hazardous occupations, and coal mining has a long history of disasters. In spite of precautions against cave-ins and explosions, the following accidents occurred in Canada in recent years:

- 1958 Springhill, N.S.—a cave-in killed 74 men.
- 1967 Michel, B.C.—an explosion killed 15 men.
- 1978 Cape Breton, N.S.—an explosion killed 14 men.

Student Book page 17

Students may not find it easy to imagine being cut off from the signals the world provides to tell us which way is up and which is down. When the familiar reference points of walls, floors, trees, and so on are replaced by the uneven surfaces of an underground cave, the result is disorientation. Students could be asked to imagine themselves waking up in a mine or a cave and having to determine what would be vertical and what would be horizontal.

A suspended mass will always be vertical. The surface of liquid in a container will always be horizontal. Practical versions of these ideas—the builder's plumb bob or the carpenter's level—may be used underground to determine when supports are vertical.

Student Book page 17

Experienced miners can tell from the flame of a safety lamp which gases are present. Methane will burn with a pale blue flame inside the wire mesh of the

lamp, and the concentration can be judged by the height of the cap of burning gas.

Carbon dioxide has a depressant effect on the lamp flame. Students could observe a school fire extinguisher, labelled CO_2, in operation, for a practical example of the effect of carbon dioxide on an open flame.

The miner's working light is now provided by a lamp attached to a hardhat and powered by a battery the miner wears on a belt. Part of the daily ritual of working in a coal mine is to check in the battery at the end of a shift so that it can be recharged.

Student Book page 18

Activity (Set-up—20 min; Duration—15 min). In this activity, the essential construction of the safety lamp is duplicated. A thermometer is set near a flame and the temperature recorded. Then a sleeve or cylinder of metal mesh is placed around the flame (demonstrating the principle of the safety lamp) and the drop in temperature is noted and recorded. Students should chart their observations.

The principle used by Sir Humphry Davy in his safety lamp should be clear now to the students. Metal is an excellent conductor of heat. Heat from the flame is conducted away as quickly as it is produced. The methane gas outside the lamp never reaches combustion temperature.

Exercise Sheet 3

Any discussion of energy reserves and resources eventually requires numbers in the millions and billions, yet most students—and adults—have only a hazy idea of the size of these numbers. Exercise Sheet 3 will help students to relate *million* and *billion* to events within their experience.

Ask the students to complete the estimate for each question before they complete the answer. The first estimates may be wildly off target, but by the end of the activity, student estimates should be more accurate. You may wish to have students refer to their estimates as *predictions*.

A billion is a thousand millions in North America and France, but a million millions in Great Britain.

Answers

1. About 12 d (11.57 d).
2. About 32 a (31.7 a).
3. 1000 L or 1 m^3.
4. $7 \times 3 \times 2 = 42$ m^3 to fill the pool. About 24 pools (23.8 pools).
5. About 2.7 a.
6. About 2739 a.

Student Book page 18

Reserves are the amounts estimated to be in the ground and recoverable.

The map showing coal resources could be used to review kinds of coal and mining methods in Canada. This map will also be needed later when the students are asked to think about the future of coal in Canada.

Answers

1. Strip mining would be used to recover those deposits that lie near the surface. Underground mining would be used for deposits that are too deep for strip mining—too much overburden would need to be removed.
2. Underground mining is needed in Cape Breton. The coal deposits lie largely below the ocean and must be reached by long tunnels.
3. Strip mining is the most economical because it saves on the high cost of constructing tunnels and shafts and because it recovers more of the coal. (Note, however, that reclamation costs are higher with strip mining.)
4. Even large deposits of coal may be untouched if the coal is of low quality. More important is the cost of bringing the coal to market. The costs of constructing

a long railroad through difficult mountain terrain in the north might raise the price of the coal produced beyond that which any coal buyer would be willing to pay.

5. Approximate percentages are as follows:
   - British Columbia—19%
   - Alberta—48%
   - Northwest Territories—5%
   - Saskatchewan—24%
   - Nova Scotia—3%

Student Book page 19

The diagram of the coal-preparation plant provides another opportunity for students to practice gathering data from illustrations. The stylized illustration on Student Book page 19 shows raw coal introduced into a system of washing tanks and shallow hoppers with grids. It might be helpful to have one or two students trace the path of the coal for the others before the class attempts to answer the questions.

Answers

1. The coal is cleaned and then sorted by size.
2. Gravity keeps the coal incoming through the system.
3. The missing part of the diagram is a crusher. To supply stoker coal, a larger size would be run through the crusher.

Exercise Sheet 4

This Exercise Sheet is an exercise in logic. Given the four screens and the pile of mixed gravel, the students' task is to choose the logical, and practical, way to proceed to five sorted piles of material.

The best way is to begin with the coarse screen and proceed in steps to the finest screen. This is not the only logical way, but the reverse sequence is not a practical way to treat fine-mesh screens.

Student Book pages 20-21

If at all possible, have the students observe the soil profile in the local area. It takes only a short time to dig a shallow hole, say 50 cm deep, to show them how thin the layer of soil is upon which we depend on for our food.

Student Book page 21

Answers

1. Rain will erode piles of spoil that are left exposed. Good reclamation practice now requires backfilling to begin as soon as possible to minimize erosion.
2. Sediment and acid solutions both find their way into water courses.
3. Lakes and rivers are the usual sources for wash water, and the temptation is to return the used water to the source. The term "black water" describes the used water. It contains coal particles and is acid from contact with the coal waste (pyrite). Storing the black water in a settling pond is one way of coping with the problem. Unfortunately, this has little effect on the high acid content of the liquid, and seepage contaminates ground water.
4. Strip mining produces clouds of dust when the vegetation is removed and both the subsoil and coal are exposed to the wind.
5. *(Answers will vary.)*

Exercise Sheet 5

The Crowsnest region in British Columbia is a strip-mining area where reclamation procedures have been planned for twenty years into the future. At present, the area has abundant elk, bighorn sheep, and mountain goats and is renowned for its fishing. The intention is to minimize disturbances to the wildlife as much as possible.

Have students work through the Exercise Sheet. When they have finished, have them share their answers in a class discussion.

Answers

1. One football field would take 100 m × 50 m × 5 m = 25 000 m^3.
   $\frac{2\ 000\ 000\ 000}{25\ 000}$ = 8000 football fields
2. Land—Spoil piles are to be graded and planted.
   Water—A dam will prevent runoff from polluting Line Creek. Bridges will be built so that heavy machinery will cross over small streams.
   Air—Coal will be stored in silos at the preparation plant. Coal cars will be sprayed to keep down dust before transport by train. Air-monitoring stations around the mine will take samples regularly.

Student Book page 22

Have students read the Student Book material and answer the questions that follow. In your discussion of the answers, draw out the fact that although strip mining causes a great deal of environmental disruption, it poses little danger to the miners themselves, whereas underground mining is exactly the reverse.

EXTENSIONS

Social Awareness Should governments play a larger role in reclamation efforts? Most states and provinces have enacted legislation to compel mining and forest-products industries to do a certain amount of reclamation and reforestation. Groups of students could be assigned to research the legislation enacted by different governments. When they have done their research, their results could be compared using questions similar to the following:

- Which government has enacted the most legislation governing reclamation? (Reforestation can be covered here too.)
- Which government has enacted the least legislation? Can you think of reasons why this is so? (The main reason may be that the area concerned has no need of this kind of legislation because it has neither mineral nor forest resources. However, even gravel pits should be reclaimed once the gravel has been removed.)
- Which province has the best legislation, in your opinion? Why?
- Which province needs to improve its legislation, in your opinion? Why?

Once these questions have been discussed, you might like to continue the discussion by asking questions similar to these:

- Do you think that the various governments should step in and reclaim areas where private companies have failed to do so? Why or why not?
- Should the negligent companies be billed for this, or should they give over their rights to the land in exchange for this service? Support your answer.

Social Awareness Taking all aspects into consideration, which kind of mining is the most harmful? You might like to ask students to consider this question in light of what they have read in Chapter 3. You might like to have individual students suggest harmful aspects of both underground mining and strip mining for a chalkboard list. When most of the harmful effects have been listed, encourage students to discuss which one is the most harmful and why, using questions similar to these:

- Which kind of mining does the most harm to the environment? Why?
- Which kind of mining affects people the most? Why?
- Are the harmful effects of mining severe enough to stop coal mining altogether?
- What would happen if coal mining were stopped? Give both good and bad results. (Students should realize that both kinds of mining—underground mining and strip mining—are harmful to people. Underground miners bear the brunt of the damage but the long-term effects of environmental damage may, in the end, affect far more people.)

Chapter 4

Using Energy from Coal

OBJECTIVES

Knowledge

- **account for the changes in the use of coal from 1950 to 1980**
- **explain how coal is used in the production of steel and electricity**
- **list some of the many by-products from the destructive distillation of coal**
- **name the harmful by-products from the burning of coal and other fossil fuels**
- **explain how acid rain is formed**
- **test the known effects of acid rain**
- **list some of the efforts being considered by industry and government to overcome the problem of acid rain**
- **identify the regions in North America most likely to show the effects of acid rain**

Process Skills

- **compare bar graphs**
- **produce coal gas, coke, and coal tar in a laboratory activity**
- **apply discovered knowledge**
- **identify solutions as acids or bases**
- **neutralize an acid solution**
- **carry out an experiment by stating the purpose, identifying and controlling the variables, making and recording observations, and stating a conclusion**

Vocabulary

acid, acid rain, alkali, alkaline, base, blast furnace, by-product, coke, condensation, control, corrosive, destructive distillation, disperse, generator, impurity, iron ore, limestone, litmus paper, mortar, neutral, neutralize, nitrogen dioxide, pestle, pH scale, prevailing winds, scrubber, specimen, steel, sulfur dioxide, turbine, variable

Materials

Student Materials—see Student Book pages 25, 28, 29, 30
Exercise Sheet 6

TEACHER BACKGROUND

In the late 1940s, the largest amount of the coal produced in Canada was used for the heating of homes. By the early 1980s, the two major demands for coal were for thermal coal for power-generating stations, and for coking or metallurgical coal used in the production of steel.

It is expected that thermal coal will be increasingly needed for the production of electricity. Alberta, at this time, uses thermal coal for most of its electrical needs, and the availability of coal in the Maritimes is expected to result in growing use for electrical generation there. Scientists do not foresee technological breakthroughs in the energy crisis before the turn of the century. In the short term, while nuclear reactors will generate some of our energy supply, coal will be used and relied upon increasingly for the production of electricity, here and in the rest of North America.

Demand for metallurgical coal is expected to grow with most of the production going to Japan to be used in its fast-growing steel-making industry. The Canadian steel industry, located in southern Ontario, has historically relied on coking coal from nearby fields in the United States.

When coal undergoes the process of heating and decomposition known as destructive distillation to form the coke used in steelmaking, valuable by-products are also formed. They are used to make a wide variety of products that are well-known to us.

A possible future use of coal in Canada is the conversion of coal into liquid and gaseous fuels as conventional fuel sources decrease.

While the phenomenon of acid rain has been known for several decades, it is since 1975 that environmentalists have become greatly concerned about it. This has happened because the effect of acid rain has become much more serious within a short time. Experts are all the more concerned as we move to greater use of coal as our supplies of petroleum become depleted.

Acid rain is formed when nitrogen oxide from vehicle exhausts and sulfur oxides from the burning of fuels by industries, such as nickel and copper smelting, react with cloud water to form nitric acid and sulfuric acid. These acids fall in the form of rain. The cumulative effect of acid rain is to make soils and bodies of water too acidic for the customary life forms. When acid rain falls in areas where there is soluble limestone, it becomes neutralized. However in areas such as the Canadian Shield, the Adirondack Mountains in the United States, and most of the land area in the Scandinavian countries, the insoluble bedrock lacks this neutralizing capability.

The noticeable effect as lakes become acidic is that the usual forms of marine life vanish. Acid lake water kills the eggs and the young of fish, and leaches calcium out of the bones of adult fish, deforming their spines. In time, as the fish disappear, the birds and mammals which depend on them for food also disappear.

Forest trees are also affected by acid rain, which causes spotting and burning of leaves. As the capacity for photosynthesis is impaired, growth is retarded. Trees weakened by acid rain are also more subject to damage from the cold of winter and from insects.

Damage to crops is another observed effect of acid rain. Signs of it have been detected on apples, tomatoes, and soybeans.

Besides the damage to our natural environment, acid rain corrodes the paint surfaces of cars, and crumbles away the surfaces of buildings, monuments, and statues.

Experts are warning that we must act now to control air pollution or risk irreversible damage.

Canada and the United States have realized that what each country does affects the other and have made attempts to work out joint strategies. Canada releases about 7 500 000 t of sulfur and nitrogen oxides into the air and the United States releases about 48 000 000 t. It is estimated that about 4 000 000 t of air pollutants are blown across the Canadian border from the United States. Similarly about 2 600 000 t of air pollutants from sources in Canada are borne southward. (*Globe and Mail*, May 27, 1981.)

In an effort to develop joint controls, Canada and the United States signed a "memorandum of intent" in August, 1980, agreeing to proceed toward regulation of air pollution. However, progress has been slow. The problem is a difficult one because pollution controls inflict great expense on industry.

Provincial governments have also been attempting to implement environmental controls. In the province of Ontario, damage to the small lakes of the cottage country has been immense. The government has acted to order reductions in the levels of emissions by the province's two largest polluters, the International Nickel Company and the Ontario Hydro Commission.

There are several ways in which Canadian industry has acted to lessen pollution. Fuels have been selected for their low sulfur content. High smokestacks have been erected, such as the 380 m smokestack at INCO in Sudbury. An effective solution to the problem is the installing of flue-gas "scrubbers" which can remove up to 90% of the sulfur oxides, and electrostatic precipitation, which removes the fly ash. These are costly installations and industries are unwilling to invest in the purifying of flue gases in this way.

The pH of a solution is the measure of its acidity or alkalinity. An acid dissolved in water produces many hydrogen ions with a positive charge (H^+). A base produces many hydroxyl ions with a negative charge (OH^-). A neutral solution has the same number of each ion.

The accurate measure of the pH of a solution in industry is made by a glass electrode with a thin glass membrane. The membrane is sensitive to the concentration of hydrogen ions. When the membrane is immersed in the solution to be sampled, an electric charge proportional to the hydrogen-ion concentration is produced. The electric current is displayed by a meter with a scale calibrated to indicate pH values.

CORE

Student Book page 23

The graphs on Student Book page 23 do not tell anything about the amounts of coal used in 1950 and 1980, but they do show how the coal was used. Students should be able to estimate percentages for each bar on the two graphs.

1950 approximate per cent		1980 approximate per cent	
electricity	20	electricity	45
railways	25	exports	30
steel	10	steel	20
industrial	45	industrial	5

Student Book pages 23-24

Answers

1. The railways converted from steam locomotives to more efficient and more convenient diesel-electric locomotives.
2. Heating by coal was changed to heating by oil or natural gas.

3. About 45% of Canadian coal is used to produce electricity. This percentage will likely increase in the future.
4. About 20% of Canadian coal is used to make steel.
5. Japan and Korea are importers of Canadian coking and thermal coal.
6. The cost of steel depends on the cost of the ingredients and less expensive ingredients are used whenever possible. Coal from the United States has been cheaper than coal from Alberta because transportation across the Great Lakes by coal freighters is very inexpensive compared to transportation by coal train from Alberta.
7. There is no known substitute for coke in the steelmaking process. If thermal-electric generating plants can be built close to both the market and an inexpensive supply of coal, then coal is still an economical fuel.

Student Book pages 24-26

Activity (Set-up—20 min; Duration—25 min). If possible, begin this activity as a class demonstration. Be very careful when heating the coal. It becomes very hot. Make sure the class knows the names of the three products of destructive distillation: coal gas, a gaseous mixture of methane and hydrogen; coal tar, a liquid mixture; and coke, a solid residue.

Answers

OBSERVATION The coal gas burned as it came out of the glass tubing.

The coke burned hotter than the bituminous coal.

CONCLUSION The three products of the destructive distillation of coal are: coal gas, coal tar (liquid), and coke (solid).

Destructive distillation of coal means the breaking down of coal into its three products.

You might like to have the class make a collection of as many of the different items shown on the by-products tree on Student Book page 26 as possible.

Student Book page 27

Students should know what an acid is, and that acids can be neutralized before they read about acid rain.

The pH scale, a logarithmic scale, will be new to the students. Each numbered point on the scale increases or decreases by a power of ten. Accurate measurement of the pH level of a solution is unfortunately beyond students at this level but an understanding of the basic chemistry of the acid rain problem is within their capabilities.

Two observations could be made about the pH scale. One is that acid rain is not usually detectable as acid without the aid of a sensitive measuring device. Acid rain is not dangerous as a shower; it is dangerous as an accumulation of acid effects over a period of time. Even granite statues succumb to acid rain.

The other observation is the fairly narrow range that soils hold on the scale. The most alkaline soils are far less alkaline than the most alkaline household solutions. The same is true for acid soils.

When students have read and discussed Student Book page 27, you could ask them to make a copy of the pH scale and color it. Ask questions such as:
- Which end of your scale would be dark blue?
- What part would you color dark red?
- How would you color the exact middle of the scale?"

The following activities use the pH scale to demonstrate acids, bases, and neutral solutions.

Student Book page 28

Activity (Set-up—15 min; Duration—30 min). This activity will give the students experience with acids and bases that are found in most households, and an experience in imagining data. To lessen the chance of spills and accidental mixings, a test-tube rack is suggested. In order to record the effects of litmus paper, the students will need to label their test tubes and have a method of recording their observations. Assist them in setting this up efficiently.

This activity provides an opportunity to emphasize safety precautions, even with these relatively mild household chemicals. In case any student has lingering ideas that scientific discovery is a happy accidental result from the random mixing of the contents of one bubbling test tube into another, remind the students there is no place in the laboratory for careless behavior.

Student Book page 29

Activity (Set-up—5 min; Duration—10 min). Students who have completed the activity on acids and bases will have found that some solutions are neutral, that is, are neither acidic nor alkaline. In this activity, they find out that an acid can be neutralized by the controlled addition of a base. Again, have students record their observations in a useful form.

Interested students will enjoy the challenge of guessing whether or not the same number of drops would be used if the situation were reversed. (The answer is yes.)

Exercise Sheet 6

The areas that will be affected by acid rain can be determined by prevailing winds and the location of sources of pollution. (In this exercise, students do not consider that soil in some areas can withstand acid rain, and in some areas it cannot.) Students will be able to conclude that the effects of acid rain cross borders but that we all share in the responsibility.

Accounts of the effects of acid rain can be found easily in newspapers and magazines. Have the students make a collection, looking for clear factual statements. Even without the sources of pollution we have today, "normal" rain would be slightly acidic. The carbon dioxide of the air combines with rain to form a weak solution of carbonic acid. Before the Industrial Revolution, normal rain tested a little below neutral on the pH scale. Today, the gradual pollution of the air over the industrialized parts of the world has made normal rain about pH 5.6. Over large parts of the world, rain and snow are from 5 to 30 times more acidic than "normal" rain.

Student Book page 30

Activity (Set-up—15 min; Duration—2-3 weeks). The effects of acid rain can be demonstrated by students in an experiment. Since an understanding of the process we call an "experiment" is at least as valuable for students as the information it produces, it is time well spent to ensure that students know the steps to follow, and the reasons for them. You may feel that you would like students to follow these steps, as a whole-class group, in a class demonstration (due to the hazards of working with sulfuric acid or because you do not have adequate space in your classroom). If so, students may assist you in setting up the experiment and then act as observers.

Hypothesis is a word that may seem unnecessarily difficult to young students, and so it has not been used. The first step of clearly stating the purpose of the experiment as a question or a statement is very important, however. Most students will have dropped the "Mad Scientist" concept, but some teachers will

be instructing students who still secretly believe that discoveries in science are achieved not by methodical procedure, but by random combinations. The control in this experiment means that there is always a standard to which changes can be compared.

Many factors, or variables, are at work in most situations. In theory, an experiment eliminates all the variables except one, and that one is manipulated and the results observed.

The students are first asked how the elodea should be distributed to achieve accurate results. Discuss what they will look for in the plants. They should consider the amount of the plant put in each lake and its healthy appearance.

When the elodea plants are placed in the lakes, the variables that affect plant growth, sunlight and temperature, have to be considered. Let the students decide where each lake should be placed to receive the same amount of light and heat.

Keeping accurate records is the housekeeping part of experimenting. It is all too easy to jot information on scraps of paper to be entered later in the right place. Have the students choose a method and procedure of recording observations that will be satisfactory, and then see that it is carried out.

The conclusions that can be made at the end of an experiment must be matched to the conditions of the experiment. Discuss with the students whether they are entitled to state that every kind of water plant is affected by acid rain. The indications are that such a conclusion is likely but, to be fair, other plants must be tested.

Student Book page 31

Students should know that combustion of all fossil fuels contributes to the acid rain problem, and that the responsibility does not belong entirely with the industries with smokestacks.

In the past, smokestacks rarely went to 100 m in height, and a height of 60 m was typical. The awareness of the problem of acid rain has prompted construction of taller smokestacks in an effort to disperse the stack effluents. Canada currently has the tallest smokestack, the 380-m stack at the ore smelters at Sudbury.

The argument for taller smokestacks is that the effluents are carried much farther, dispersion is greater, and therefore the concentration of unwanted gases and particles is decreased. Discuss the argument with the students.

EXTENSIONS

You might like to assign the following to your class for research. Students' presentations could be displayed in the classroom.

- Study the Coal By-Products Tree. Select a few coal by-products with which you are familiar from each of the three major branches: coal tar, coke, and coal gas.
- Locate picture illustrations of each of your choices from magazines and newspapers.
- Sketch your own By-Products Tree on a large sheet of paper. Mount your pictures on the appropriate branches.

Able students might like to identify *all* the variables that might affect the results of the acid-rain experiment with: plants (kind, size, condition, age); containers (size, shape, material); location (sunlight, temperature); water (amount).

Social Awareness Pollution control—whose responsibility? Students should be aware that the issue of pollution control is an ongoing concern. A current-events exercise could be to bring in newspaper and magazine clippings that tell what is happening now.

Chapter 5

Energy from Petroleum

OBJECTIVES

Knowledge

- **explain the theory of the formation of petroleum**
- **explain how petroleum deposits are located by seismic survey**

Process Skills

- **calculate the distance across a body of water using seismic principles**

Vocabulary

bacteria, echo principle, geologist, impermeable, organic, porous, seismic survey

TEACHER BACKGROUND

The first major oil discovery on the North American continent was in Canada. At that time, petroleum was used to produce chewing gum, paint, and kerosine. No one recognized the importance of the find.

The first North American deposit was discovered in 1858 by a carriage maker named Williams as he dug in some "gum beds," near Sarnia at the site of the town of Oil Springs. At a depth of 18 m, he discovered a sufficient quantity of oil to process and market as lamp oil. In 1862, a second well was drilled which produced at a rate of about 2000 barrels a day. Prospectors flocked to the area, drilling wells, and producing more oil than could be handled. Much of it was disposed of in nearby rivers. By 1895, wells were producing 800 000 barrels a day. The area has largely been exhausted but a few wells continue to produce a very small quantity to this day.

The Canadian industry moved west at the turn of the century when natural gas was found near Calgary. It was soon moving in pipelines to heat southern Alberta homes, to power the industry and to light the streets of Calgary.

Turner Valley in Alberta became the site of the first large-scale drilling for crude oil in the Canadian west in 1914. The industry was centered in this area for many years, however by the early 1940s production had declined to a point where 90% of Canada's needs were being met by imported oil. In 1947, Leduc No. 1 was drilled. It was of tremendous importance to the industry. It was the largest petroleum deposit yet discovered in Canada.

Canada continues to explore for new deposits of oil. Promising results are being seen from drilling efforts in the Beaufort Sea and off the coast of Newfoundland and Labrador.

The science of exploration, geology, by which drilling sites are selected, involves collecting and interpreting information. In some cases, there are surface indications of the presence of oil. Sometimes outcroppings of the sorts of rock formations in which oil is found may be seen on the surface. Occasionally there are surface seepages of oil or gas. More often, scientists must take measurements with special tools before they can predict the likelihood of oil. A device called the magnetometer can detect layers of sedimentary rock because such formations have lower magnetic properties. Another instrument, a gravimeter, measures gravity pull; dense rock increases gravity pull. The seismograph uses the echo principle to measure distances as sound waves from dynamite exploded in holes at the earth's surface are reflected from deep-lying rock formations. Seismic measurements can also be taken under the sea.

CORE

Student Book page 32

Students may need help in comprehending the time period involved in the formation of petroleum. Encourage them to develop time-lines to pictorially represent it. Review the definition of *fossil fuel* with them.

Answers

1. Crude oil is the fossil form of ancient plant and animal life that has been transformed by burial under rock sediments over a long period of time.
2. Organic material is alive, or is the remains of plants and animals that once were alive.
3. Oxygen, milk, carbon dioxide, water vapor, natural gas, molasses, and toothpaste are classed as fluids.

4. Sedimentary rocks have formed from the sediments deposited by moving water. Crude oil is the fossil form of plant and animal life buried under sediments that changed to rock.
5. It is believed that the plant and animal life that produced petroleum existed in ancient seas that covered much of the earth.
6. Crude oil and natural gas are both forms of petroleum.
7. Exploration for petroleum deposits is still active because not all promising areas have been test drilled.

Student Book page 33

Students will benefit by understanding how the principle of echo-sounding can be used to measure the distance across the lake in the example given.

If an echo resounds across a lake in 4 s and sound travels 344 m/s, the distance across the lake is calculated as follows:

$$\frac{4.5 \times 344}{2} \text{ m}$$

Remind the students to divide by 2 because the distance travelled by the sound is double the width of the lake.

EXTENSION

Social Awareness When a petroleum deposit is located, to whom does it belong? This question could be used as a newspaper and magazine research project for interested students. They should realize that provincial and federal governments often disagree on the question of resource ownership. They should be able to find a great deal of material in current periodicals to outline the various points of view. When the research has been gathered, you might like to divide the class into two groups, one to present the provinces' point of view, and one to present the federal government's point of view.

Chapter 6

Extracting and Processing Petroleum

OBJECTIVES

Knowledge

- **explain how petroleum deposits are reached and how petroleum is brought to the surface**
- **explain how petroleum deposits that lie under the ocean are reached**
- **describe the nature and extent of the oil-sands deposits in Alberta**
- **describe the processes used to mine the oil sands**
- **explain how synthetic crude oil is extracted from the oil sands**
- **investigate methods of transporting oil from offshore-drilling rigs**
- **explain how oil is transported from the well to the refinery over land and across water**
- **explain what distillation means**
- **explain how the principle of distillation can be used to separate liquids with varying condensation temperatures**

Process Skills

- **construct a model oil well**
- **draw a scale diagram**
- **construct a model of oil-sands extraction**
- **apply the principles learned from models to real-life situations**
- **observe the principle of distillation**
- **interpret results**

Vocabulary

batch, bitumen, bucketwheel, Canadian Shield, cargo, casing pipe, Christmas Tree (valve), condenser, derrick, distillation, drilling bit, exploratory, fireflooding, fraction, fractionating tower, friction, huff and puff, *in situ*, muskeg, permafrost, petrochemical feedstock, pipeline, steam injection, synthetic, tailings, tanker

Materials

Student Materials—see Student Book pages 35, 38, 45
Exercise Sheets 7, 8, 9A-D, 10, 11

TEACHER BACKGROUND

When indications favor the presence of oil in a new area of drilling, an exploratory well called a wildcat will be drilled. About one in ten wildcat operations is successful in locating oil. Fewer yet are successful in finding oil in marketable amounts.

As new wells are drilled, information on rock formations is recorded daily in a log. Rock cuttings from drill bits and drilling mud may show promising signs of the presence of oil. Instruments are passed down into the drill holes to record information and transmit it to the surface by electrical cable. If one of the oil finds is a large one, tubular steel casing is passed into the well and cemented in place. The well then is fitted with wellhead machinery that will make it a producing well.

The "gusher," a spectacular fountain of crude oil shooting into the air, is part of the romantic past of the oil industry. Today a gusher is a sign of bad judgment or accident and is rarely seen. However, the underground pressures that produced the gusher are still found today. Controlled by pipes and valves, underground pressures bring the crude oil and natural gas to the surface. When pressures drop, pumps must be used.

Another source of petroleum in Canada is the land along the coast that lies under the ocean. When one considers the derrick, the machinery, and the crew needed to drill an oil well on land, drilling into the sea bed for oil under 90 m of water seems impossible. This is how it is done in the Hibernia oil field, 300 km from Newfoundland.

Special methods are needed for drilling offshore. Seawater must be kept out of the drill hole and the oil—if any is found—must be kept in the drill hole so that it will not pollute the water and the fishing grounds. Divers can reach the bottom, but they can't give much assistance to the drilling at this depth. Water pressures are so great on the bottom that work time is very limited.

The drilling platforms have to be very sturdy to withstand the waves and high winds of storms at sea. A special problem for the rigs drilling off Newfoundland is the threat of icebergs. Huge blocks of ice break off from glaciers in Greenland and drift south every spring. They move slowly—about one kilometre an hour. But the energy of the huge mass of water in the ocean currents forcing an iceberg to move is so great that the push of the moving iceberg can't be resisted.

Experiments to blow the icebergs to pieces, or to tow them away, have not been successful. The only answer seems to be a drilling platform that can be disconnected from the drill hole and towed out of danger when icebergs are near.

Getting the oil from the drilling platform safely to shore is another problem. The easiest way would be a pipeline along the seabed from the platform to the shore station. The icebergs make that solution very risky. Icebergs float low in the water—only one-eighth of the ice is above water. The immense mass of a slow-moving berg of rock-hard ice is enough to gouge trenches in the bottom. And the pipelines can't be buried because much of the bottom is rock.

The size of the oil-sands deposits in Alberta, and the amount of recoverable petroleum (estimates vary up to supplies that will last two hundred years) make the oil sands one of the truly exciting frontiers in Canadian science and technology. The first known use of the oil sands was to waterproof the seams of birchbark canoes. The first Europeans to explore the region were intrigued by the outcroppings of oil sands, and inventors have been interested ever since. It is tantalizing to realize that an immense amount of petroleum is available if only an easy, inexpensive way can be found to separate the petroleum from the sand. The history of the oil sands is a story of repeated attempts and failures to find a practical method of extraction and separation. Today, the conclusion is that such a process is possible, but expensive. Improvements will be made, but no magical breakthroughs are anticipated. Oil from the oil sands will probably continue to be "the most expensive oil in the world."

When production was begun at the Leduc Oil fields in 1949, it was immediately apparent that an effective method was needed for getting crude oil to the markets in eastern Canada. In 1950, the Interprovincial pipeline connecting Edmonton, Alberta, to Superior, Wisconsin, was built in just one hundred and fifty days. A tanker route through the Great Lakes connected Superior to Sarnia, Ontario. In 1953, the tanker route was replaced by an underwater pipeline linking the two cities. Finally, the pipeline was extended to Toronto and Montreal. The Interprovincial pipeline at 3105 km is the world's largest.

A second pipeline was built in 1953 to carry crude oil westward to British Columbia. The Trans Mountain Pipeline, which is 1155 km long, crosses the rough terrain of the Rocky Mountains.

The cost of constructing pipelines is very high. A length of pipeline constructed ten years ago in the rocky interior of British Columbia cost one million dollars for each three kilometres, and the cost continues to rise.

Imported crude oil from Venezuela and the Middle East enters Canada from the east coast.

There are limits to the chemistry of the refinery. Only the products that are in crude oil to begin with can be separated out by the refinery, but the processes that do this have become much more efficient over the years.

Oil and natural gas provide the raw material, or feedstock, for the growing petrochemical industry. Petroleum is made up of hydrocarbon molecules; that is, molecules in which atoms of carbon are combined with atoms of hydrogen. It is a characteristic of the hydrocarbons that the combination can be broken up and recombined in hundreds of different ways, and each new combination is a new chemical with its own structure and physical properties. When these new chemicals are useful, they become products.

In a process that recalls the cracking units of the refinery, the feedstock is subjected to heat and pressure in the presence of a catalyst. The hydrocarbon molecules break apart and recombine to produce a powder or a liquid. These basic petrochemicals are usually processed and refined by other petrochemical manufacturers into more complex, and more useful forms.

CORE

Student Book page 34

Ask the students what difficulties there might be in getting oil to the surface. In some areas, such as in southeastern Alberta, drilling may be completed in two or three days. In the foothills of the Rockies, drilling may be carried on for eight to ten months before oil is reached. Students should consider why some operations take longer. Oil in southeastern Alberta lies at depths of about 450 m and is beneath layers of soft sandstone. In the foothills of the Rocky Mountains, it lies 4500 m under layers of hard rock. Question students on the effect of drilling through hard rock on drill bits. At greater depths, drill-bit changes take longer.

Exercise Sheet 7

A familiarity with the basic parts of the drilling rig will help students to answer questions such as the following:

- What is the derrick for?
- What turns the drill pipes and the drill bit?
- Why don't the cables above the drill pipe get tangled when the pipes turn during drilling?

Exercise Sheet 8

This exercise gives students practice in using a scale. The students should be directed to consider the largest number first in deciding which unit to use. If students find that the scale chosen will make the drawing too large for the paper, they then will have to make the choice of using a smaller scale or a larger piece of paper, such as mural paper.

Student Book page 35

Activity (Set-up—15 min; Duration—20 min). This activity creates a model that helps the student to understand why crude oil in the ground is under pressure. (The oil will be forced up through the straw due to the pressure applied.)

Be sure to choose jars that are wide enough so that a student can comfortably place a hand inside.

Exercise Sheets 9A-D

This game duplicates some of the hazards and rewards of exploring for oil. Since exploration operates partly by chance and produces many dry holes, the players have to locate the oil deposits on the map partly by chance and partly by strategy. Regions on the map are named by letter and number co-ordinates, similar to other games with which the students will be familiar. Strategy enters the game as the players try to use previous unproductive guesses to refine a guess.

You may wish to control the game to the extent of providing the gameboard for the Banker with squares (locating oil deposits) already colored in.

Once the players become Developers, they draw one card each turn from the pack of cards provided. These 32 cards provide the students with some of the details in the story of exploring for oil. When problems arise, there are slowdowns (the player misses a turn) and the player may pay out money. When things go well, the player collects money. The game winner is the player with the largest holdings of property and money at the end of the game.

Provide each player and Banker with one copy of the gameboard. There should be one or two copies of the game instructions for the players. Each player should have one copy of all money cards. The Banker should have four copies of all money cards. The Banker should have one copy of each bank loan card and three copies of each banking money card. Make one copy of each of the Developer Cards.

Student Book pages 35-36

Ask the students to imagine the difficulties to be encountered in the installation of drilling platforms and rigs at sea. Have them consider factors such as the violence of winter storms, the high waves, and low temperatures that must be dealt with as well as the difficulties of getting personnel and materials and supplies to the drilling platform. The usefulness of helicopters for transporting people and goods to offshore-drilling rigs may be mentioned.

Students who are familiar with ice only as ice cubes or hockey rinks may be surprised by the physics of icebergs. To make the point clear, it may be worth the trouble to prepare a block of ice to represent an iceberg that is slightly smaller than the container, perhaps an aquarium, in which you plan to float it. Prepare the block of floating ice, but mask the lower part of the container. All that should be visible is the part of the ice that one would see when looking at an iceberg from the platform of an offshore-drilling rig. Ask the students to imagine that

situation. Remove the mask from the container. Ask the students to estimate how much of the ice is above water (one-eighth) and how much is below (seven-eighths).

Solutions to the problem of transporting oil to the shore from an offshore well can be posed by students. Ask students to be creative and inventive in their solution. For example, someone has suggested a new solution to the problem of controlling flood waters in cities and towns. The present method is to fill bags with sand and pile them to make a wall, but sand is not always available where and when it is needed. The new solution is to take plastic bags to the flood area—and fill the bags with water. Perhaps this idea may not work for practical reasons, but it is a creative and inventive solution to a problem.

Answers from the students may include: filling up barges to be towed ashore; floating pipelines that can be disconnected and moved; a floating refinery so that the oil does not need to be moved; bigger and more powerful tugboats to move the icebergs; powerful magnifying glasses that use solar energy to cut large icebergs into smaller chunks; and so on.

Student Book pages 37-38

Activity (Set-up—15 min; Duration—24 h). Ideally, the students should be supplied with genuine oil sands. If that is not possible, try making a substitute by mixing sand with used motor oil.

This activity can become rather messy. Scattering newspapers over lab benches will reduce the amount of cleanup. There are some unpleasant smells but there is no danger if normal precautions are taken. If glassware is used, it can be cleaned in a two-step process using a solvent and then a strong dishwasher detergent. Another suggestion is to use old, previously soiled glassware.

It is suggested that the large tin can be the size of a soup can, and the smaller can be the size of a fish can. Plastic spoons are useful for skimming the bitumen.

The amount of NaOH is not critical, and perhaps different groups could use different concentrations and then compare results. Air can be bubbled into the mixture (when less than 80°C) using a blowpipe constructed from glass tubing.

Student Book page 38

Answers

CONCLUSION Bubbling air would be helpful in separating bitumen from oil sands because the bitumen clings to the air bubbles and floats to the top.

Yes. Bubbling air in my experiment caused the bitumen to float.

The reasons other groups had different amounts of bitumen recovered was caused by variations in the amount of bitumen in the oil-sand samples. *(Oil sands are not consistent. There should be about 8-17%.)* Some groups also bubbled through less air.

The dry sand and dry bitumen masses are different due to evaporation. *(Loss of mass is probably caused largely by evaporation of water film on the sand and other moisture in the oil sand.)*

Bitumen flows slower than water or oil. It is similar to honey, syrup, glue, molasses, ketchup, driveway sealer, and tar.

The viscosity of bitumen can be reduced by adding heat and by thinning it with other liquids. *(Also by refining—cracking and fractionating.)*

A simple demonstration to show students how viscosity changes with temperature can be made with molasses. Cool two test tubes of molasses in a refrigerator overnight. Heat one in a boiling water bath. Then, compare the rate at which the warm and cool molasses flows.

Student Book pages 39-40

Direct the students to read about the two kinds of oil-sands extraction methods being used—strip mining and *in situ*. Strip mining for oil sands is similar to the operation for coal. The overburden is removed, and the oil sands are transported to an extraction plant. Students can make the comparison with coal mining.

The *in situ* methods of extraction are unique to the oil-sands deposits, and are attempts to solve the problem of oil-sands deposits that are deep in the ground. Although there are different methods, the principle behind them is the same. Have the students read to find out how the methods are similar.

Student Book page 40

Answers

1. 50 m.
2. Oil sand—The mixture of petroleum and sand that lies in large deposits in Alberta in the regions around Cold Lake, Fort McMurray, and Peace River.
   Bitumen—The thick, tar-like form of petroleum in the oil sands.
   Tailings—What is left of the oil sands when the bitumen has been extracted. The tailings are toxic and have to be kept in ponds.
   Synthetic crude—The extracted and upgraded bitumen. It is roughly comparable to crude oil obtained from oil wells.
3. Strip mining and *in situ* methods.
4. *(See Student Book pages 39-40.)*
5. *In situ* methods are less expensive because the overburden does not need to be removed. A part of the upgrading and separation process has taken place in the ground.
6. Recovery of bitumen by *in situ* methods is not as complete as with strip mining. The condensed water is contaminated and presents a disposal problem.
7. Oil from the oil sands is more expensive.

Exercise Sheet 10

Before the next sections that deal with the transportation and refining of petroleum, you may wish to use this activity as a review. Students compare coal and petroleum under four headings: origin, formation, location, and extraction.

Student Book pages 41-43

In some ways pipelines typify some of the problems facing Canadians because of the size of the country. The oilfields that produce the oil and the market where that oil can be sold are separated by great distances, and in some cases, formidable terrain. Technology which links together widely separated parts of the country with railroad, telegraph, and radio, does it again with the construction of pipelines. Students should be aware of the large part that technology plays in a country where distances are great and communication and transportation difficult.

The map of Canada on Student Book page 43 could be used to set the stage for this section. Encourage the students to read the section and answer the questions.

Student Book page 43

Answers

1. Pipelines can operate all year round, independent of the weather and almost independent of human beings.

2. The market. Refineries are built close to large markets, and the pipelines supply the refineries. As markets change and new refineries are built, pipelines change, too.
3. Protection from weather changes, vandalism, and accidental damage are provided by the trench.
4. The company must secure right-of-way from the owners of the land and agreement from local and federal governments.
5. At 4 km/h, it would take more than thirty-two days.
$\frac{3100}{4} = 775 \text{ h} = 32 \text{ d}$
6. The rise in price for imported oil is forcing us to look to our own oil resources, and to conserve our oil resources by switching to natural gas.
7. Construction is easier south of the Great Lakes than in the Canadian Shield. There is also the possibility of providing petroleum to the American market.
8. Mountainous terrain, permafrost, and the rocks of the Canadian Shield are all obstacles to the new pipelines.
9. Observers would look for signs of oil leaks.

Student Book page 44

One minor reason why tanker cargo space is divided into sections is that it is possible for the tanker to carry more than one kind of cargo. The main reason is to give stability to the ship. Having many cargo holds instead of one cargo space is like carrying a number of glasses full of water on a tray compared to carrying the same amount of water in a shallow pan.

Exercise Sheet 11

This exercise will require the student to use what has been learned in this section. Each of the routes proposed presents both advantages and environmental hazards. There are three answers possible. The student's task is to choose the best route.

Route A Have students examine the tanker route in an atlas. The narrow Strait of Juan de Fuca, crowded with shipping and sometimes fogbound, presents real hazards. Have students read about the shellfish and salmon fisheries of the west coast of Canada. Route A has the advantage of supplying crude oil to the west coast, and the markets of the prairies, as well as to markets in the east.

Route B All the details of pipeline construction should be recalled to analyze this route. It would be fairly easy to establish a refinery near the middle of this route to provide for western markets, although the route proposed is well to the north of large cities.

Route C Have students examine the details of this tanker route in an atlas. Have the students find out how long each year the Northwest Passage is open to shipping and what must happen during the rest of the year if tankers are to use the route. No pipeline is required with this route, and therefore transportation costs will be much lower.

Student Book pages 45-46

The heart of the refinery process is the separation of crude oil into components by distillation.

Student Book page 45

Activity (Set-up—15 min; Duration—20 min). If the equipment is not available for the students to use, it would be useful if you were to demonstrate the distillation principle yourself.

Ask the students to observe the temperature in the flask the first time the liquid

boils. Students will remember that water boils at 100°C, but will note that the flask mixture boils at approximately 80°C.

Ask what happens to the liquid when it boils and relate the answer (vapor) to the drops that form in the condenser. Ask why cold water, rather than hot water, is used in the condenser. (It is more efficient in cooling the vapor from the flask.)

When the flask stops bubbling, most of the alcohol has been evaporated. An increase of heat will boil the water which can be condensed as before. This liquid will retain some of the odor of alcohol.

The key observation for the students to make is that the alcohol evaporated while the water remained in the flask. You could, if you wish, apply the idea to a hypothetical case—a flask of five mystery solutions to be identified. Supply the different boiling temperature of each liquid. Ask students how they would identify the five liquids.

The transfer of the distillation principle to the fractionating tower should present no problem if the students have seen or performed the demonstration with water and alcohol. The flask contained a mixture—petroleum is also a mixture—and the components of the petroleum evaporate at different temperatures.

Answers

OBSERVATION

	Liquid 1 80°C to 85°C	*Liquid 2* 95°C to 100°C
appearance	boiling	rapidly boiling
odor	strong	little or none
burns	yes	no

The mixture began to boil the first time at 80°C. The evaporating liquid condensed because it hit a cooler surface.

CONCLUSION Liquid 1 was alcohol because it burned. Liquid 2 remained in the flask because a higher temperature was needed for it to boil.

Student Book page 46

Answers

1. Liquid 1, the alcohol, would have condensed at the top of the tower. Alcohol boils at a lower temperature than water, and it condenses at a lower temperature than does water.
2. Fractions in order of boiling points, highest boiling point first: heavy fuel oil, lubricating oil, heating oil, jet fuel, gasoline.

EXTENSIONS

What is life on an offshore-drilling rig like? Interested students may research this topic investigating subjects such as: methods for transporting personnel, goods, and materials; methods of supplying energy for heat, light, and power; living conditions for workers; and so on.

The oil-sands extraction activity can be tried, by interested students, using potassium hydroxide, table salt, and detergents.

To gain an understanding of the approximate size of a tanker ship, a scale drawing could be made representing outlines of the side-view of an oil tanker measuring 400 m long and 25 m high and a bungalow measuring 16 m long and 7 m high. Students might also wish to draw to scale an overhead view of an oil tanker 400 m long and 70 m wide, and a football field 100 m long and 50 m wide.

Chapter 7

Using Energy from Petroleum

OBJECTIVES

Knowledge

- **recognize that the refinery turns crude-oil fractions from the fractionating tower into more than 1000 different products**
- **recognize that natural gas will provide heat, fuel, and the raw material for products in the petrochemical industry**
- **explain what effects oil-sands extraction has on the environment**
- **explain why oil is spilled on land or on water**
- **explain why oil spills can be damaging to the land and sea environment**
- **explain what eventually happens to organic materials, such as oil**

Process Skills

- **apply discovered knowledge**
- **measure a circle graph**

Vocabulary
boom, butane, cracking, density, emulsification, ethane, Grand Banks, habitat, hydrogen sulfide, impurities, methane, plankton, propane, sulfuric acid

Materials
Student Materials—see Student Book pages 50, 51
Exercise Sheet 12

CORE

Student Book pages 47-48

You may wish to review students' knowledge of the uses of crude oil and natural gas. The use of petroleum products as fuels for industry, transportation, and heating should be well known to most students. They have probably themselves used lubricants in bicycles and roller-skates and can readily understand the wide use of petroleum-based lubricants in industry.

It would be interesting to assign a few students the task of collecting samples, or illustrations, of the great variety of refinery products unknown to the other students. Leave the samples and illustrations on display briefly, with one question to be answered, "What do these products have in common?"

Alternatively, a display of the by-products of petroleum could be started now with this section, groups of students taking responsibility for bringing samples or illustrations for each category of petroleum products. Leave space in the display to accommodate the products that could be added after the students read about natural gas.

Exercise Sheet 12

When students find a circle graph during research, they may want to know the percentage, and the real numbers, that each part of the graph represents. This activity shows how to determine it.

Each section of the circle will have to be measured with a protractor, so it may be necessary to remind, or instruct, the students in its use.

Answers

	Degrees	Percentage
gasoline	130°	36%
furnace oil	47°	13%
heavy fuel oil	68°	19%
diesel oil	43°	12%
petrochemicals	7°	2%
other	65°	18%
Totals	360°	100%

At least two observations can be made about the graph. Half the oil we refine in Canada goes toward keeping us warm and fueling our vehicles, and, the large variety of useful products from the petrochemical industry is supplied by only 2% of our oil.

Student Book page 49

You may wish students to review what they have learned previously about petroleum extraction methods. Encourage them to consider the entire process from location to use of petroleum in regard to environmental consequences before they proceed to the next section.

Student Book pages 50-51

The activities on these pages will help the students gain some necessary familiarity with the behavior of oil with water as they attempt to understand the problems associated with an oil spill at sea.

Student Book page 50

Activity (Set-up—5 min; Duration—15 min). Any oil can be used in this activity. Used motor oil is perhaps closer in appearance to crude oil, but salad oil would also be satisfactory.

In following the procedure the students will observe that a drop of oil on water takes a circular shape. The thickness of the oil will be great enough in the first stage to be clearly visible. The oil spreads out gradually, and the layer becomes thinner.

If you choose to carry this activity on long enough, the students could be encouraged to be inventive and creative. Soaking up the oil with absorbent material like a paper towel is only one possibility. Ask them what other materials could be used. Ask them if they could translate your method into a full-scale operation on Canada's sea coast. Could they remove the oil with a straw? (Allow students to raise only edible oils, *not* motor oil, by sucking on a straw.)

Some students may discover that the use of booms to contain oil slicks, although very simple, has proven effective where the water was reasonably calm.

Answers

OBSERVATION and **CONCLUSION** The oil spreads out on the water surface.

The drinking-straw boom contained the oil slick and permitted it to be moved.

Oil can be removed from the water's surface by absorbent materials soaking it up, or by suction from the surface.

Student Book pages 50-51

Oil spills at sea come from two sources—tanker accidents and offshore-drilling accidents. The extent and nature of damage to the undersea environment caused by oil spills is still being investigated. Disruption of life cycles, and hazardous substances entering the food chain are two possibilities with long-term effects.

Offshore drilling continues. By April, 1979, more than 135 holes had been drilled in the seabed around the Maritime provinces.

Student Book page 51

Answers

1. Tanker mishaps include running aground because of fog, high wind, tides and currents, or loss of engine power. Fires and explosions are always a threat with a flammable cargo. In heavy seas, the hull of a tanker bends and flexes as it rides up and down the waves. Sometimes the stress is too great. Every year there are reports of tankers breaking in two during a storm.
2. The system of pipes and valves, which is designed to contain the great pressures sometimes encountered when the oil deposit is reached, can fail.

Icebergs can damage or demolish an offshore rig. The pipeline system of moving the oil from the offshore well to the shore refinery can be damaged by ice.

Student Book page 51

The brief reference to density in this section is not intended to be an introduction to the topic. Most students are surprised and intrigued by the idea that liquids thicker than water are, at the same time, not as dense as water. The examples that illustrate this should be known to all students. Oil floats; water is denser. Ice floats; water is denser. Cream floats; milk is denser. Basswood floats; water is denser.

Activity (Set-up—10 min; Duration—20 min). Although oil and water do not mix, some strange things happen to oil and water under certain circumstances. This activity is useful because it explains how oil, which usually floats on water, can be made to sink. During this activity, the students should be able to make the following observations.

1. The oil in the bottom of the test tube rises to the surface of the water.
2. The oil partly breaks into drops, and gradually rises again to the surface of the water.
3. The oil and water will both take the form of tiny drops.
4. There will be a slow separation into the constituents, water and oil.

Their conclusion should be that oil and water do not make a true mixture, but both will break up into tiny drops, and these tiny drops will stick together to make a foam.

Student Book page 52

Answers

1. Oil slicks may disappear because of emulsification. The liquid oil is changed physically into a foam that may contain so much water that is barely buoyant. The addition of small amounts of any material may sink it.
2. The decay of buried oil slicks would take place slowly because the bacteria would be starved of oxygen.

Student Book pages 52-53

Marine biologists fear that oil spills may disrupt the aquatic food web. The relationships are complex and involved. A diagram of the flow of energy through this ecosystem results in a triangle, and the label "energy pyramid" is often attached to this triangle. An abbreviated and simplified version is presented to the students. Interested students could be given a more complete diagram and asked to trace the various food chains that make up the pyramid, and perhaps identify some of the organisms in those food chains.

The Grand Banks will likely be familiar to students as a name and perhaps a location. To understand why this area is so favorable to fishing, students will have to revise their idea of "shallow." Compared to the depth of the ocean past the continental shelf, the Banks are shallow. You may wish to make a scale drawing of various ocean depths to illustrate the point.

Those who fish on the Banks see oil spills as a threat to their livelihood. Students will understand why when they consider the food chain. The ocean food chain in the diagram, though abstract and simplified, illustrates the flow of energy through the chain, the dependence of any level on the level below, and the small amount of energy that is left over to be passed on to the level above. Ask students what could happen to the food chain if the organisms in one layer were reduced by poisonous substances.

Student Book page 53

Answers

1. The Grand Banks is a very large area. It is shallow enough that sunlight penetrates to the bottom. It is the meeting point of two ocean currents, one bringing warm water, and the other bringing cold water and nutrients. The combination creates immense food supplies in a favorable habitat.
2. If one layer were destroyed, the pyramid might collapse. More likely, some organisms would disappear and others, in time, would adapt to new conditions. In the short term, the effect on fishing would likely be disastrous.
3. Physical or chemical effects of an oil spill could disrupt the life cycle of an important fish species.
4. In the food chain illustrated, 10 000 kg of plankton would begin the chain by capturing energy from the sun. The end result would be a 1-kg fish for us to eat. (At each stage there is a 90% loss of energy.)
5. The main feature of the Arctic Ocean compared to the Grand Banks is the low temperature. One would expect to find:
   - less variety of life forms
   - fewer individuals for each variety
   - slower growth rate
   - less ability to recover from any setback

EXTENSIONS

Social Awareness If all the oil used in Canada had to come from the oil sands, what effects would the high price of oil have on Canadians? Is the extraction of oil sands worth it? In attempting to answer such questions, most students will not really be aware of the immense costs involved in extracting oil from unconventional sources such as the oil sands. It takes 2 t of oil sand to yield 1 barrel (160 L) of synthetic crude oil for the refinery. The oil-sands mining, extraction, and upgrading costs must be added to the usual costs of refining crude oil. Some students might like to do research on the processes to find out how much the immense machines and installations cost to buy and operate. Other students might want to look at the social disruption that has been caused wherever the search for oil has been undertaken. When the results of their research have been presented to the class, a discussion based on the following questions may be useful.

- Is self-sufficiency in oil important enough to justify oil-sands extraction?
- Would the money spent on oil-sands extraction be better spent on looking for more easily accessible oil?
- Should this money be spent on social services for those people in the north whose way of life has been completely changed by the search for energy?
- Should the taxpayers' money be used to subsidize the extraction of this enormously expensive oil? Would it be better to use the money to lower the cost of the imported oil that most taxpayers use already?

The petrochemical industry produces a wide range of products from petroleum. Students could also consider how their classroom environment depends on products of the petrochemical industry. They could attempt to imagine a classroom of the 1900s and contrast it with the classroom of today. They could consider how present-day clothing has been affected by the replacing of natural fibers, such as cotton and wool, and natural materials, such as leather and rubber, by synthetics made from petroleum.

Social Awareness Ask some students to collect opinions about the sources of recent oil spills. Since tanker mishaps get the most publicity, most people will name tanker accidents as the main cause.

Chapter 8

Energy from Uranium

OBJECTIVES

Knowledge

- **recognize how uranium deposits are located**
- **explain the difference between uranium and stable materials**

Process Skills

- **calculate the amount of radiation to which an individual is exposed**

Vocabulary
atmosphere, element, fission, geiger counter, millirem, ore, radiation, radioactive, rem, uranium

Materials
Exercise Sheet 13

TEACHER BACKGROUND

Exploration for uranium has taken place in British Columbia but no producing mines exist in that province. Most of the activity at present is in northern Saskatchewan where exceptionally high-grade deposits are being found and mined. One of these mines, Beaverlodge, went into production in 1953. Other major deposits are mined in the Blind River and Bancroft regions of Ontario.

Areas favorable for uranium mineralization occur across Canada, particularly in the Canadian Shield area and in the western mountain regions. Curiously, many coal deposits are found in areas where uranium deposits occur as well. As a result, all coal contains traces of radioactive elements which are released when the coal is burned.

The earth's stores of uranium were created during the same catalysmic event that formed the other elements of which the earth and everything upon it is made. The significant difference, where nuclear energy is concerned, between uranium and the other elements is the instability of uranium's nucleus. That instability results in the emission of particles of energy from the atom's nucleus, in what is referred to as radioactivity.

The sun's energy, as heat and light, radiates from the sun to the earth. It is therefore called radiation.

The word *radiation* is also used to refer to a very special radiation which should more properly be called *ionizing radiation*. Ionizing radiation is a higher energy of radiation than ultraviolet radiation, for example, that can produce suntans, or with indiscriminate exposure, painful sunburn.

Ionizing radiation can be considered in the same way that solar radiation is considered: its intensity is reduced by distance; it can be blocked by shielding materials; and, its effects are related to the length of exposure. As a rule, the damage done by radiation is in proportion to the dose received, that is, the amount of energy deposited in body tissues. It is assumed that this relationship extends down to zero, that there is no such thing as an absolutely harmless level of radiation. While this can be demonstrated at high doses, it is not as clear at low doses. Since everyone is exposed to background radiation, it is not possible to have a control population, exposed to no radiation at all, to which can be compared the health of populations exposed to varying levels of radiation. Since there are areas in the world where populations live in background radiation levels that are fifteen times greater than those experienced in Canada, it is assumed that the human body can tolerate some level of radiation over that which is received from natural sources. International agencies responsible for assessing the hazards of radiation recommend that no one should add more than five hundred millirems per year to the dosage received from natural and medical sources.

CORE

Student Book page 54

Students will all be familiar with sunburn, so it makes a convenient starting point for a discussion about radiation. The sun emits a great deal of energy but because of the distance between the earth and the sun, only a small fraction of that energy reaches the earth. Students have all experienced changing levels of energy reaching the earth as clouds shield the sun or as the earth rotates and night falls, cutting off the sun's direct energy completely.

Discuss the nature and dangers of radiation with the students. They should know that a small annual dose of radiation is our natural condition, and is apparently harmless; and also that exposure to a large amount of radiation is lethal.

Exercise Sheet 13

Have students complete this chart. Most will be surprised at the variety of radioactive sources.

Chapter 9

Extracting, Processing, and Using Energy from Uranium

OBJECTIVES

Knowledge

- **tell the story of the uranium cycle from exploration to nuclear reactor**
- **describe an atom**
- **give a simple explanation of fission**
- **explain how electricity can be produced from uranium**
- **list the advantages of producing electricity by nuclear reactor, and the disadvantages**
- **list some of the beneficial ways radioactivity is being used**

Process Skills

- **construct an atomic model**
- **apply discovered knowledge**

Vocabulary

atom, deuterium, electron, fission, isotope, neutron, neutron bombardment, nucleus, proton, radium, radon, reactor, sterile, thyroid gland, yellowcake

Materials

Student Materials—see Student Book page 56

TEACHER BACKGROUND

The three main parts of an atom are protons, electrons, and neutrons. Protons and neutrons form the nucleus of an atom; the electrons are in energy levels outside and orbiting this nucleus.

Each element has a characteristic number of protons (atomic number) in the nucleus. For example, hydrogen has one, boron has five, nitrogen has seven, neon ten, and so on. Atoms always have the same number of electrons as they have protons, but the number of neutrons can vary in two atoms of the same element (isotopes). Ordinary hydrogen has one proton, one electron, and no neutrons but deuterium, an isotope, has one proton, one electron, and one neutron. Tritium, another isotope of hydrogen, has two neutrons and one proton in the nucleus.

Protons and neutrons have about the same mass, but electrons have a mass of about 0.000 55 of a proton. The electron mass is so small it can be ignored. The mass of a given atom is therefore found in the nucleus. It is made up of the protons plus the neutrons, and is called the mass number. Since the number of neutrons can vary, scientists have averaged out the number of neutrons in all of the isotopes of an element and added this to the protons to get the atomic mass. Any periodic table will indicate that for each element there are two numbers. The smaller number is the atomic number (protons) and the larger number is the atomic mass (protons plus average of neutrons).

Because uranium atoms are unstable, they can be prompted into even more radical changes than simply emitting some energy or a particle out of their nucleus. With the proper urging, an atom of uranium can be split in two (fissioned), releasing energy as heat, and two or three particles which in turn can be used to start even more fissions and the release of additional energy and particles. This process can be likened to poking a water-filled balloon with a stick. If the balloon is poked so that the strength of the balloon is not exceeded, the vibrations set up by the poking gradually disappear and the balloon returns to a restful state. Some poking, however, will cause such severe shape distortions that the strength of the balloon at some point becomes less than the pressure of the water within it, and the balloon bursts, spilling its contents. If only the balloon would heal itself, forming two smaller balloons and spilling only a few drops of water, the analogy would be complete, because that is what the atom does. The drops of water can be likened to the neutrons released when an atom of uranium fissions, and the two smaller balloons, to the two new elements, sometimes radioactive, that result from the one larger uranium atom.

There are two isotopes of uranium—uranium-238 and uranium-235. The least plentiful of these, uranium-235, is important to nuclear energy because with a little prompting, it can be made to release energy at a far greater rate than it normally does because it is radioactive. That energy is expressed as vast quantities of heat which can be used in a variety of applications.

A reactor is the machine that assembles the right kind of fuel and produces neutrons of the right energy to induce vibrations that cause uranium atoms to split. Since it is much easier to slow neutrons down (simply by giving them something to bump into) than to speed them up, that is the principle followed in developing reactors.

Both Ontario Hydro and Atomic Energy of Canada Limited are attempting to solve the problem of nuclear-reactor waste in regard to the used, but still radioactive, fuel bundles. At present, Ontario Hydro simply stores them. Cesium 137 and strontium 90, both biologically dangerous ingredients, need a minimum of three hundred years to decay to a harmless level; highly dangerous plutonium 239, at least eight hundred thousand years. Machines pluck a few of the spent bundles out of the pressure tubes every day and send them through an underground tunnel into a concrete water bay which resembles an indoor swimming pool. There, with water shielding the radiation, they cool off. At present output, the bay has an eleven-year storage capacity.

By 2000 there may be many tonnes of nuclear wastes—enough, in Canada alone, to cover a football field to a depth of 4 m. AECL will likely choose a three-phase program: holding the wastes in water during the cooling period; sealing them in steel or other metal and putting them in well-ventilated concrete bunkers from which they can be retrieved if we wish to reprocess the plutonium; and, someday, burying them in some impermeable geological structure.

Perhaps the greatest peril is the so-called "plutonium curse." Plutonium is a by-product of nuclear fission. The amount remaining in spent fuel has a potential energy yield nearly equal to that of the original uranium, so future energy conservation will probably dictate that it be recycled. But plutonium can also be used to manufacture atomic weapons. Many fear that as supplies of extracted plutonium increase, there will be constant danger of accidents or theft.

CORE

Student Book page 55

Since the mining of uranium is similar to the operation for recovering coal, have students compare the two processes. They should note that the main difference between coal extraction and uranium extraction is in the amount of processing the rock must undergo.

Have students read the section on the atom before they begin to construct atomic models.

Student Book page 56

Activity (Set-up—15 min; Duration—20 min). To make the models meaningful, tell the students their creations will represent atoms of real substances. You could use the following, for example:

- boron—5 protons, 5 electrons, 5 neutrons
- nitrogen—7 protons, 7 electrons, 7 neutrons
- neon—10 protons, 10 electrons, 10 neutrons

Student Book pages 56-57

Have the students compare the generation of electricity by coal with the diagram using uranium. Students will observe that there is no difference except for the fuel. The nuclear reactor is being used because it produces a lot of heat.

Have students read the description of fission on Student Book page 57, and ask several students to explain the process in their own words, perhaps using the models they made previously to demonstrate.

Then have the students study the diagram of the CANDU reactor and the brief description in the Student Book. Have them discuss how the reactor uses the fission principle to generate heat. Make sure that they understand that the heat is the important by-product of fission by asking such questions as:

- What does the fission of uranium do in a reactor?
- How is this similar to the burning of coal in a furnace?
- What is the difference between a coal-fired generating station and a nuclear-powered one?

Student Book page 57

Answers

1. When a nucleus splits in two, the neutrons fly off at 42 000 km/s (releasing heat) and hit other atoms, creating a split in these atoms—beginning a chain reaction.
2. A nuclear reactor promotes an atomic chain reaction.

Student Book page 58

Have the students read Student Book page 58 and answer the questions that follow. They should understand that the uses, as well as the hazards of radiation are related to the level of energy that the particular radioactive material is emitting.

If radiation is to be used for inspecting metal welds and castings, for sterilizing medical supplies, or for treating cancer, elements like cobalt-60, which give off high-energy radiations over long periods, must be used. If the purpose is to trace a broken water pipe or to examine the functioning of an organ in the body, materials which emit appropriately lower levels of radioactivity are used.

Answers

1. Radioactive isotopes are used to treat cancer of the thyroid gland in the neck and radioactive cobalt is used to treat many other forms of cancer.
2. Industry uses isotopes to make measurements such as checking the efficiency of welding, regulating the thickness of paper, tracing materials in flow systems, and preserving food.
3. Radioactive isotopes are used to study pollution by having researchers place isotopes in cottage drainage systems, checking the path that the drainage water takes to make sure that it is not escaping into the lake.
4. Insects are exposed to radiation to make them sterile and thus decrease their population, preventing their damaging crops in the future.

Student Book page 59

Because nuclear energy is a contentious issue, your class might like to read this section and then discuss the points raised, using the questions in the Student Book as a basis for discussion. Once this discussion is over, have the students record their answers in their notebooks.

Answers

1. Nuclear reactors do not add to the acid-rain problem because they do not produce smoke, ash, or sulfur dioxide.
2. Some possible answers include the following:
   - no acid rain
   - produced from Canadian fuel
   - a lot of electrical energy from a small amount of fuel
   - can build reactors where they're wanted
   - no pipelines needed
   - good safety record of reactor operation
   - production of useful radioactive isotopes
   - can save fossil fuels for other uses
3. Some possible answers include the following:
   - Miners are endangered.
   - Mine tailings are both poisonous and radioactive.
   - Nuclear waste is piling up and we still don't know what to do with it.
   - Reactors may be called "safe," but the threat of disaster is always there.

EXTENSIONS

Social Awareness Should we continue to extract uranium? This topic can be assigned to individual students for research and subsequent discussion using the following statements:

- Uranium should not be mined because the mining of it is too dangerous to the miners, and the mine tailings pollute the nearby environment with dangerous radioactive wastes.
- Uranium should be mined. It is a valuable natural resource and provides jobs in northern communities where jobs are scarce. Proper safety precautions and waste storage methods protect miners and the environment.
- Uranium should not be mined. The more that is mined, the more that has to be sold. The CANDU reactors that use the uranium convert it to plutonium that can be used to make atomic bombs. We do not want to add more countries to the atomic club.
- Uranium must be mined. If we don't mine it, and sell our CANDU reactors, someone else will. Why should we let others take money from our pockets? Our system is safe, and we sell only to trustworthy countries who will not use the plutonium to make bombs.

Encourage students to consider the consequences of a cessation of uranium mining. Such consequences might include:

- Electricity produced from uranium in reactors would have to come from other sources. (Are those other sources available to other countries that need electricity? Is the use of those other sources more or less harmful to the environment?)
- If uranium is removed from world markets, the availability of nuclear weapons might also be reduced. (How would this affect world balance of power?)
- The unavailability of uranium might affect international competition for the remaining reserves of oil. (What influence might that competition have on the stability of nations?)

Encourage students to investigate the latest uses of radioactive isotopes in Canada, and around the world. This is the other, "friendly," side of radioactivity.

Chapter 10

The Future of Nonrenewable Energy Sources

OBJECTIVES

Knowledge

- **organize the facts learned about the extraction and use of coal**
- **predict how the use of coal in Canada may change in the next ten years**
- **describe what effects those changes in the use of coal will have**
- **relate the use of petroleum as a source of energy to the larger picture of human history**
- **discuss alternatives to solve the problem of petroleum shortages**
- **relate the use of uranium as a source of energy to the larger picture of human history**
- **recognize new ways in which uranium could be used**
- **explain the benefits, and the environmental effects, of coal, oil, natural gas, and uranium**

Process Skills

- **apply discovered knowledge**
- **interpret statistical information**
- **interpret bar graphs**
- **interpret a time line**
- **interpret a circle graph**
- **create a new graph**
- **present information in a way that will persuade adults to change their attitude on a specific topic**

Vocabulary
slurry

Materials
Exercise Sheets 14, 15, 16
Exercise Sheet 2 (optional)

TEACHER BACKGROUND

Those who search for statistics on reserves of coal, petroleum, and uranium will likely be confused by the conflicting data. The difficulty is that information about reserves varies from specific knowledge of visible coal seams to speculations about geological formations. It is claimed, for example, that there are four hundred and seventy-five billion tonnes of coal in Canada. Of this, perhaps one hundred billion tonnes can be recovered. Of this, about thirty billion tonnes are called "proven" reserves. Of this, it is estimated that twelve billion tonnes are definitely recoverable. Half of this amount, or six billion tonnes, can be mined now with present technology.

The reviving interest in the conversion of coal to synthetic fuels, a process called liquefaction, is a direct consequence of the changing economic picture. The technology has been known since World War II, and was developed in Germany as a way of fueling the German war machine without dependence on uncertain supplies of petroleum. After the war, petroleum prices were so low there was no incentive to revive the process. Now interest is growing again. South Africa is producing synthetic oil in small quantities, but new processes are expected to triple the amount able to be produced now. The Japanese, Americans, West Germans, and British are all investing heavily in developing a more efficient version of the process.

As with coal, statistics that state how much oil we have can be confusing if not carefully interpreted. The following terms can be used when petroleum reserves are the topic.

"Initial in place" is an estimate, and it refers to the volume of petroleum calculated to be available before anything has been produced. No assessment about the percentage recoverable is made, so initial in place describes much larger volumes of oil and gas than we will ever see.

"Established reserves" refers to numbers describing the amount of petroleum estimated to be recoverable.

"Ultimate potential" is an educated guess that takes the geology of an area into account.

Because uranium is so widely distributed on the earth in such greatly varying concentrations, reserves are calculated according to the cost of recovery ($US). Again, the question of what amounts can actually be recovered is impossible to say with accuracy. Analysts divide resources into two categories: "reasonably assured" and "estimated additional." Recent estimates are that if uranium sold for $80/kg, reasonably assured resources would total 230 000 t at the same price.

If the prices rise to $130/kg, the reasonably assured reserves rise to 259 000 t and the estimated additional—to 770 000 t. The estimate as to how long Canadian uranium reserves would last, producing at the maximum of which Canada will be capable in 1990, range from thirty to one hundred years. Whether Canada ever produces uranium at its maximum attainable production remains to be seen. At present rates of production, Canadian uranium would last considerably longer.

On the world scene, the span is much the same when conventional reserves are assessed. When unconventional reserves are considered, the amount of uranium available becomes much larger, although generally at a higher cost. Uranium can be recovered from gold-mine tailings in South Africa and in the United States; from phosphate rock used in making fertilizer (a plant in Calgary is already doing so); from certain copper deposits; from coal; and ultimately, from sea water which is estimated to contain some four thousand million tonnes of uranium.

While these reserves are sufficient for a long time using today's technology, advanced reactor fuel cycles, such as the breeder reactor being developed in Europe and the United States and advanced CANDU reactor fuel cycles, could extend the reserves by sixty or seventy times, providing nuclear fuels far into the future.

CORE

Student Book page 60

Students may benefit by skimming the earlier sections on coal mining in the Student Book as well as by reading these pages. The table of resources could be a calculator exercise. When students describe the effects of a change in the use of coal, they should deal with all of the effects described earlier.

Answers

1. Total resources (millions of tonnes) 63 628; total predicted demands (millions of tonnes) 119. At this rate, our coal will last for about five hundred and thirty-five years.
2. Coal may be used to fuel all thermal-generating stations. It may be converted to jet fuel, diesel fuel, and heating oil.
   Advantages: We would not need foreign oil; oil would not need to be used for fuel; oil could be used entirely for petrochemical feedstocks.
   Disadvantages: More environmental damage from strip mining; more mining accidents; more acid rain from coal-burning generating stations.

Student Book pages 61-62

The time line should serve to assure students that the world has operated for a long time without petroleum, and therefore could continue to do so. Some students might like the task of describing the adjustments we would have to make if the change were abrupt: "The Day the Oil Pumps Stopped."

The graph that depicts reserves of petroleum in the oil sands looks very encouraging. Ask the students to note that the large part of the graph is labelled "Potential"; that only a small part of this "Potential" is ever recovered; and that oil from the oil sands is costly.

Discuss how consumption could be cut back so that we make best use of our supplies. Ask the students how they and their families could contribute to a reduction in the demand for petroleum. Discuss the reasonableness of the suggestions.

Student Book page 62

Answers

1. The 1-mm line represents 125 a.
2. If the time line is 255 mm long, it represents 31 375 a.
3. The high cost of oil has to be met by raising the price of anything that involves oil. Not only do we suffer from rising prices, but there is a constant drain on Canadian dollars to the oil-exporting countries.
4. Imported oil comes from the Middle East, Venezuela, and lately from Mexico.

5. *(Students should not consider a great expansion of hydroelectric energy as a reasonable choice. Most of the convenient sites in Canada have already been developed.)*
6. *(Answers will vary.)*
7. *(Answers will vary.)*

Student Book page 62

Have the students read the section on uranium on Student Book page 62. The questions in the Student Book could be used as the basis for a discussion on the future. Encourage the students to think of the obstacles that need to be overcome if uranium is to become the fuel of the future.

Student Book page 63

This section and the questions following it can serve as a review of what the students have learned. Exercise Sheets 14 and 15 can be used to review vocabulary and some of the environmental effects of primary-energy sources.

Exercise Sheet 14

The students can write in point form what they recall about environmental effects. Be sure students consider, for each Energy Source, extraction (mining), transportation, refining, and use.

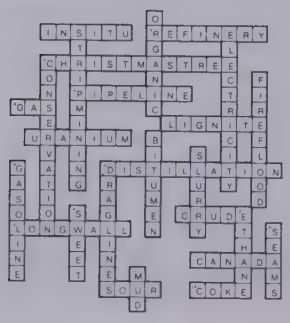
Answers

Energy Source	Effects on Land	Effects on Water	Effects on Air
Coal	Strip mining disturbs the land. Refuse in large amounts. Acid mine tailings.	Acid drainage from refuse piles.	Acid rain (sulfur and nitrogen oxides) particles.
Oil	Pipeline construction damaging in north.	Oil spills from tanker accidents and offshore drilling.	Contributes to acid rain.
Natural Gas	Pipeline construction damaging in north.		Contributes to acid rain.
Uranium	Radioactive waste. Mine tailings.	Increase of water temperature at reactor site.	Some radioactive emissions.

Exercise Sheet 15

This crossword puzzle is essentially a vocabulary review.

Answers



Exercise Sheet 16

This exercise is about attitudes and the difficulty of changing them. When the students survey adults to find out what the adults think about recycled oil for their cars, they will likely encounter the same attitude that other surveys have found: "Not in my car."

Theoretically, there is no reason for this opposition to recycled oil, but car owners have been informed, by advertising and other sources of information, that frequent changes of oil are essential for the proper maintenance of an automobile. The task the students have is to create advertising to change the negative response to recycled oil.

This should be treated as a light and interesting activity. Ask the students to bring in their favorite ad from TV, radio, or magazines. (TV and radio ads can be written out.) Try to find out why these ads are considered effective.

Have the students conduct a survey of adults who own cars or trucks with the question, "What is your opinion of using recycled oil in your vehicle?" A class discussion of the results of the survey should serve to define the problem, or problems. Ask the students to think about the approach they should take to change the attitudes of Canadian car owners. Is it information that is needed? Do car owners need to be convinced that recycled oil is safe? Should they appeal to their duty as good citizens? Finally, encourage them to create an ad for radio, TV, or a magazine, as outlined on the bottom of the sheet.

EXTENSION

Encourage students to apply what has been learned as well as demonstrate their attitude to energy. Ask them to imagine themselves as someone having the responsibility for plotting Canada's energy future for the next ten years. Their task is to consider the alternatives, make choices, and explain the advantages and disadvantages of their decision.

This exercise requires time and effort and would make a good group exercise. There should be opportunity to present comments about and criticism of the work of each group. If you do not choose to do this, each group could be assigned the additional task of commenting on the work of another group.

The conclusion of this exercise would be a good time to hand out Exercise Sheet 2 (the energy-opinion survey) once again. The results should form the basis for a class discussion, especially if the results from the first survey have been kept and can be handed out for comparison.

Nonrenewable Sources of Energy
Exercise Sheet 1

For use with Chapter 1

Sources of energy can be classified as renewable or nonrenewable.

Renewable sources of energy are sources that will continue to be available to us for an unlimited period of time. Natural processes will restore them.

Nonrenewable sources of energy are sources that will be available to us for a limited period of time only. Natural processes are not able to restore them.

1. Using the definitions above, classify the following energy sources.

coal	natural gas	wind
crude oil	uranium	wood
waterfalls	sunlight	oil sands

Renewable	**Nonrenewable**

2. Upon which class of energy sources is Canada depending today? Why?

3. What changes do you think will take place in the next twenty years? Why?

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Nonrenewable Sources of Energy
Exercise Sheet 2

For use with Chapter 1

In this survey you record your opinion. There are seven sets of statements about energy and seven opinion scales, like this one.

COMPLETELY DISAGREE **NEUTRAL** **COMPLETELY AGREE**

Read each set of statements. Decide what *your* opinion is.
Mark a point on the scale that you think would match your opinion.

1. We have plenty of gasoline now, and more petroleum is always being discovered. There is no need to conserve gasoline.

COMPLETELY DISAGREE **NEUTRAL** **COMPLETELY AGREE**

2. Cars don't pollute the air. They have special controls on them that prevent pollution.

COMPLETELY DISAGREE **NEUTRAL** **COMPLETELY AGREE**

3. Cars save you time and time is valuable. If I owned a car, I would use it to go everywhere.

COMPLETELY DISAGREE **NEUTRAL** **COMPLETELY AGREE**

4. Providing energy for us in usable forms, such as electricity, gasoline, and furnace oil, uses up a lot of energy.

COMPLETELY DISAGREE **NEUTRAL** **COMPLETELY AGREE**

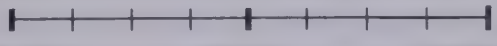
5. I don't use much energy. I don't even own a house or car.

COMPLETELY DISAGREE **NEUTRAL** **COMPLETELY AGREE**

6. Coal and wood were fuels for my grandparents. Coal and wood are outdated fuels.

COMPLETELY DISAGREE **NEUTRAL** **COMPLETELY AGREE**

7. Individual people don't cause pollution. It's the factories that cause pollution.



COMPLETELY DISAGREE **NEUTRAL** **COMPLETELY AGREE**

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Nonrenewable Sources of Energy
Exercise Sheet 3

For use with Chapter 3

To talk about energy we need numbers in the millions and billions. How big is a million? How much bigger is a billion? This exercise will give you a better idea of these huge numbers. First review the place value chart.

BILLIONS			MILLIONS			THOUSANDS			ONES			
H	T	O	H	T	O	H	T	O	H	T	O	
								4	0	0	0	FOUR THOUSAND
					4	0	0	0	0	0	0	FOUR MILLION (1000 TIMES GREATER THAN 4000)
4	0	0	0	0	0	0	0	0	0	0	0	FOUR BILLION (1000 TIMES GREATER THAN 4 000 000)

1. Your heart beats about once a second. How much older will you be one million heart beats from now?

   Estimate _____ Answer _____

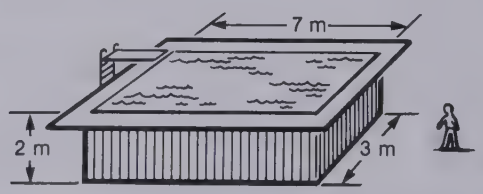
2. How much older will you be one billion heart beats from now?

   Estimate _____ Answer _____

3. Imagine a leaking tank that drips once each second. Each drop is 1 mL of water. In about twelve days, one million drops will leak from the tank. How many litres, or cubic metres, of water will that be?

   Estimate _____ Answer _____

4. In about thirty-two years, one billion drops will fall from the leaking tank. How many backyard swimming pools this size could you fill with one billion drops?



   Estimate _____ Answer _____

5. Suppose you could spend $1000 a day, every day of the year. How long would it take to spend one million dollars?

   Estimate _____ Answer _____

6. How long would it take to spend one billion dollars the same way, while spending $1000 every day of the year?

   Estimate _____ Answer _____

In North America, 1 billion is written as 1 000 000 000.
(In some countries, the word *billion* stands for a different number.)

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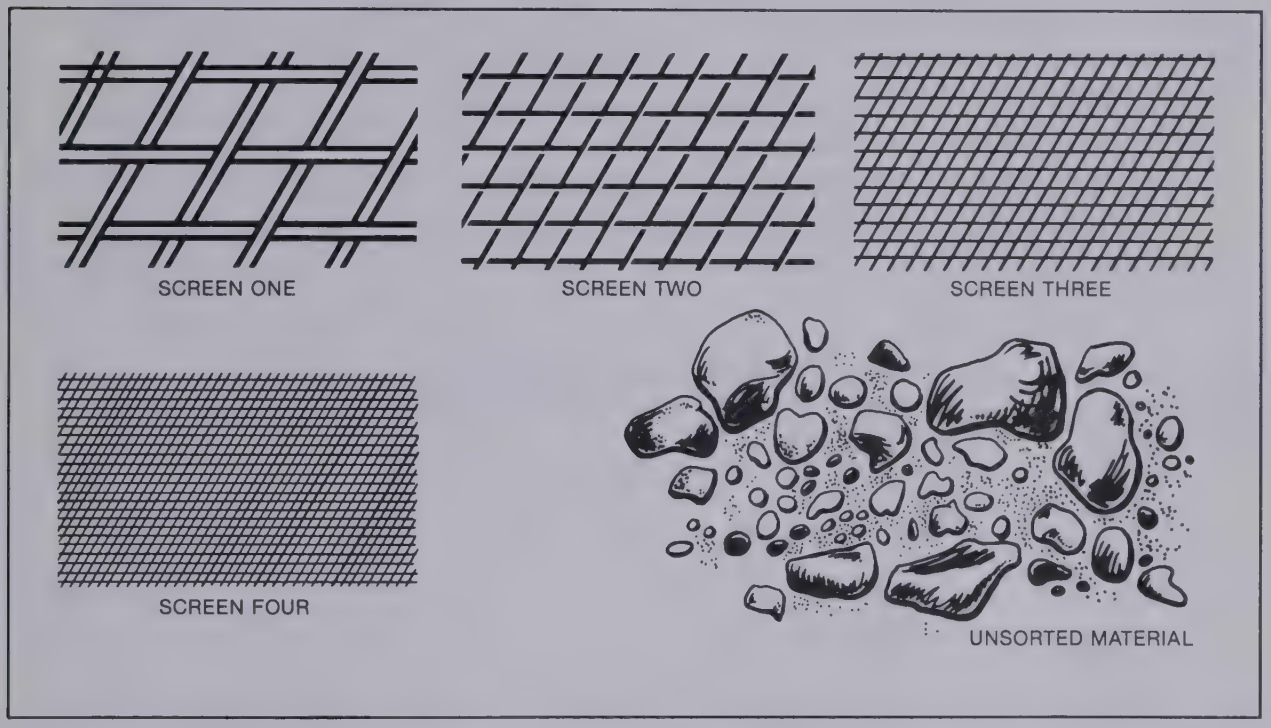
Nonrenewable Sources of Energy
Exercise Sheet 4

For use with Chapter 3

In this exercise, you will choose a sorting procedure. Imagine that you are given four screens the same size, with mesh sizes as illustrated, and a pile of unsorted material as illustrated.



1. The task is to sort the pile of material into five piles. What procedure would you use?

2. Explain why your way is the best.

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Nonrenewable Sources of Energy
Exercise Sheet 5 — For use with Chapter 3

A new coal mine is being opened at Line Creek in the Crowsnest region of British Columbia. Over a period of twenty years, the overburden of half a million tonnes of rock will be stripped away and about 1 500 000 t of coal will be removed.

The overburden will be hauled to a valley by trucks and be dumped. A dam will be built to prevent runoff from the piles of spoil contaminating nearby Line Creek. The spoil is to be graded and planted with grass, shrubs, and trees. Temporary bridges across small streams will be built so that heavy machinery will not damage the mountain-stream environment.

A rail line will haul the raw coal 10 km to a coal-preparation plant. There the coal will be screened, washed, sorted, and stored in silos to wait for shipment by rail.

When the coal is loaded into the open rail cars, it will be sprayed with a material that forms a thin, hard coating. This is to prevent coal dust from blowing around during the rail journey.

To measure the effect of the mining operation on the air, monitoring stations have been set up in the area. Samples of the air will be taken every month.

1. The total amount of overburden and coal to be removed is about 200 000 000 t. Imagine a football field 100 m by 50 m that is buried 5 m deep in rock and coal. How many football fields could be buried like this with 200 000 000 t of rock and coal?

2. A strip-mining operation that removes so much coal and lasts for twenty years can have long-lasting effects on the land, the water, and the air. Find examples of plans to keep damage to a minimum in each environment.

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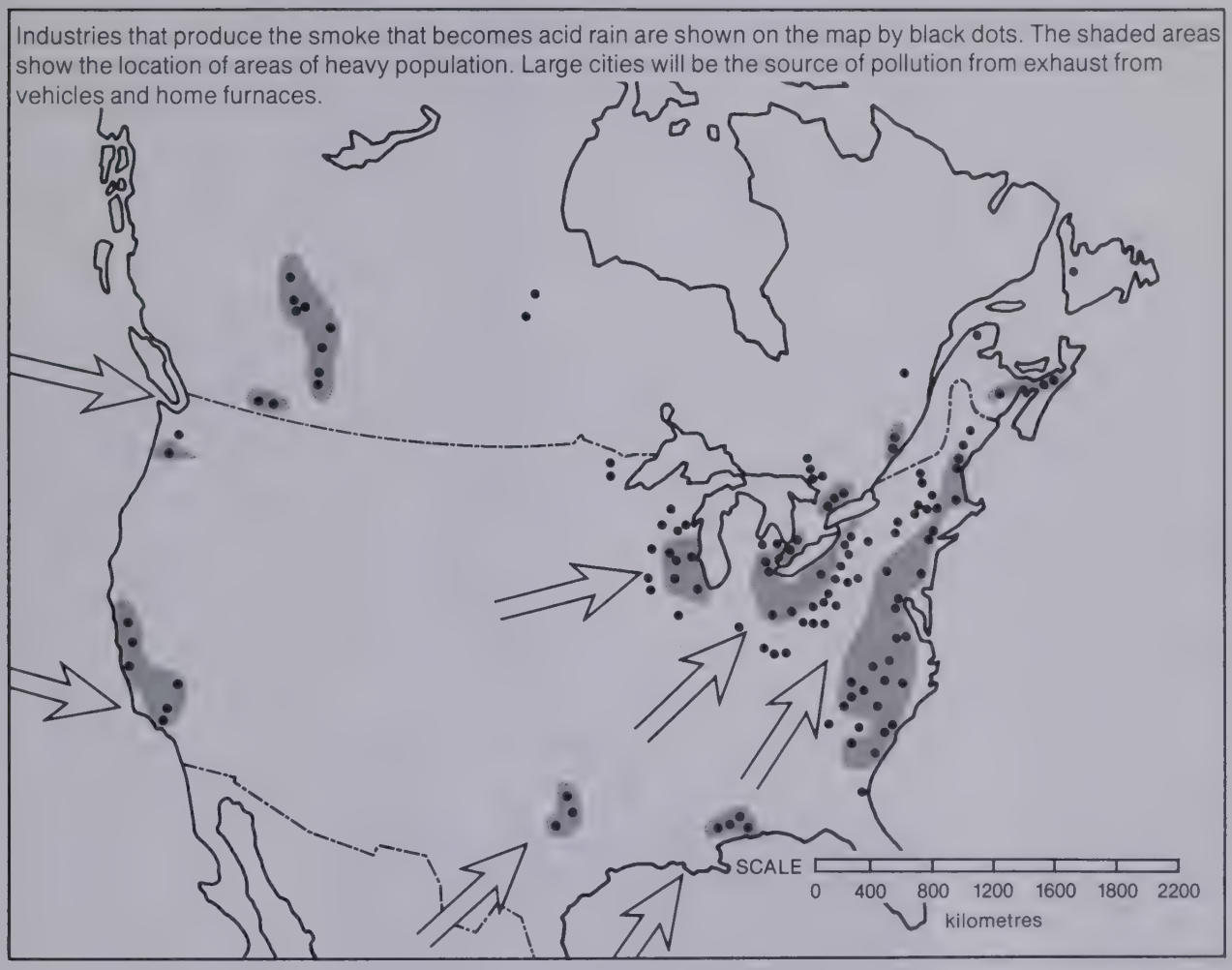
Industries that produce the smoke that becomes acid rain are shown on the map by black dots. The shaded areas show the location of areas of heavy population. Large cities will be the source of pollution from exhaust from vehicles and home furnaces.
SCALE
0 400 800 1200 1600 1800 2200
kilometres

1. The direction of the wind changes from day to day, but over a longer period of time the wind tends to blow from the same direction in any one area. These prevailing winds are marked on the map with arrows. Color these prevailing wind arrows black.
2. Acid rain may fall many hundreds of kilometres from the smokestack or automobiles that caused it. Consider wind direction, the number of dots, and the concentration of people on the map. Shade the areas where you think acid rain will fall. Show a heavy fall of rain with a heavier color.
3. In general, are the people who get the acid rain the people who caused it?

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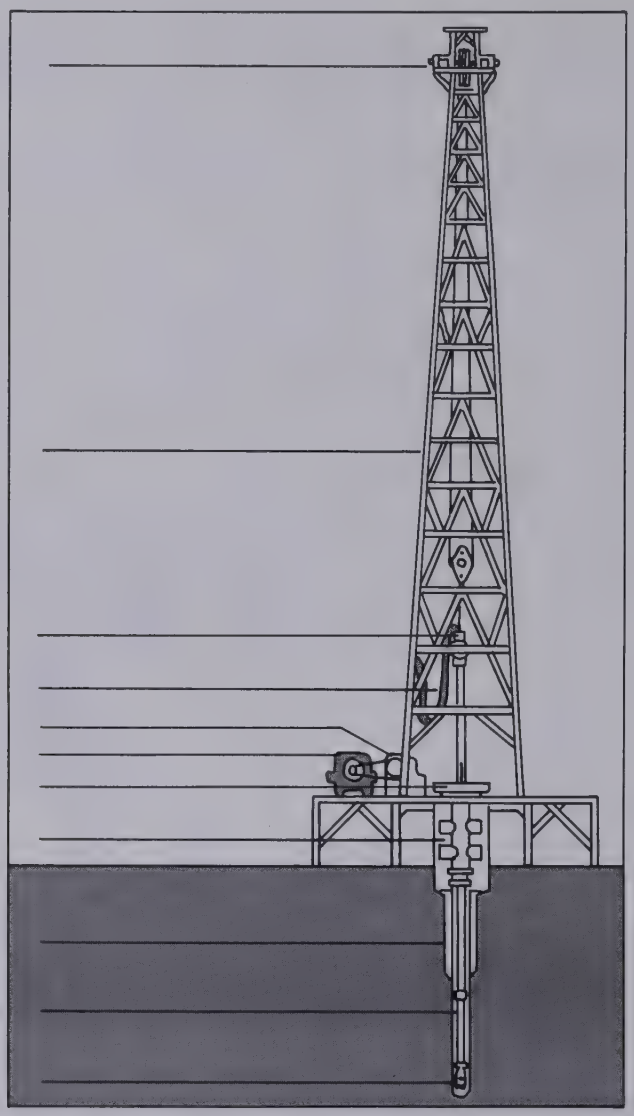

Label the following features of a drilling rig.

- swivel
- derrick
- engine
- mud hose
- drill pipe
- rotary table
- drill bit
- mud or drilling fluid
- mud pump

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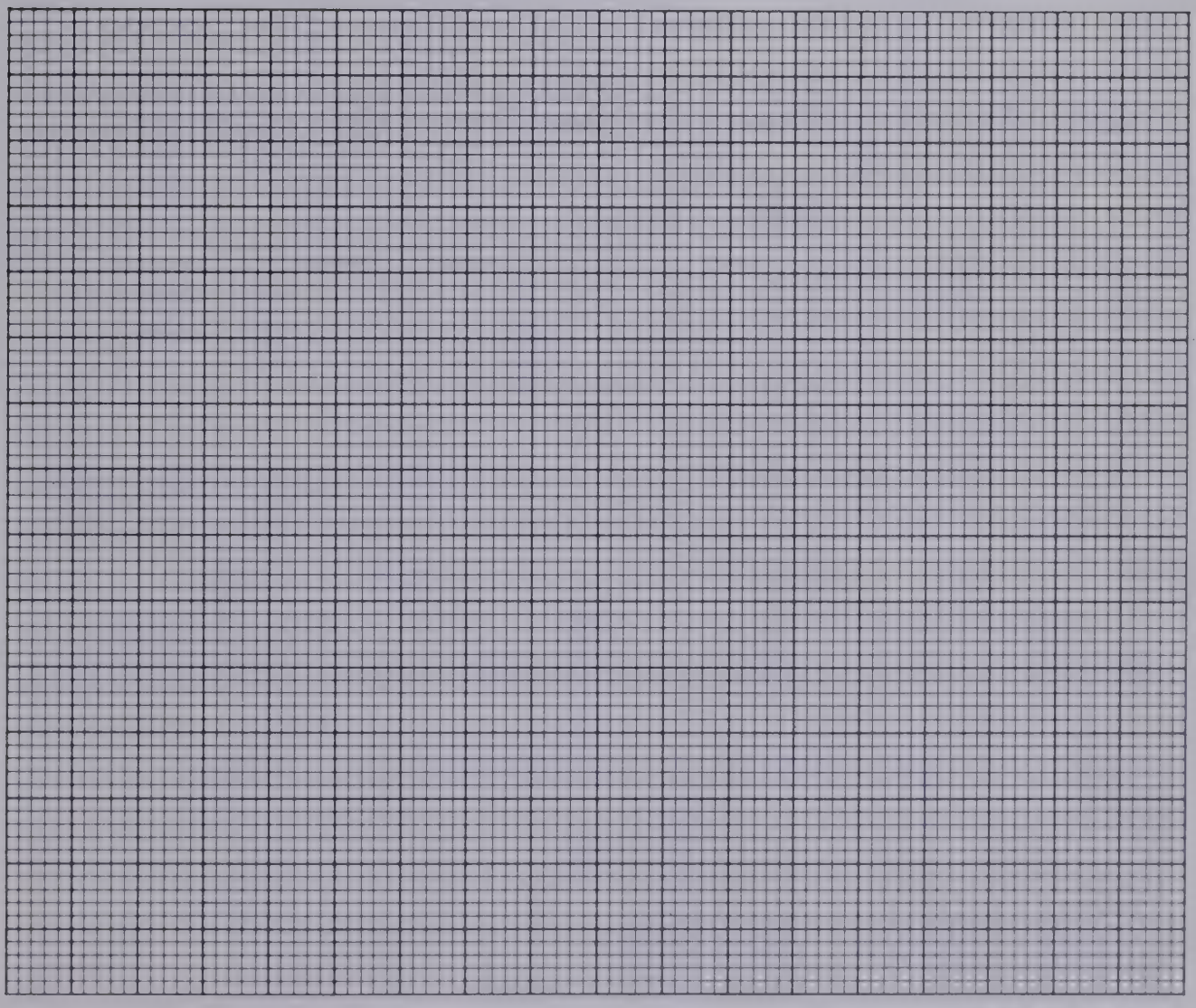
Nonrenewable Sources of Energy
Exercise Sheet 8

For use with Chapter 6

Make a scale drawing to show the following information.

1. A large derrick can be 50 m high.
2. Canada's first oil well was 44 m deep.
3. The average well in Canada is about 1200 m deep.
4. Wells in other parts of the world are as deep as 6300 m.



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Tycoon

In this game, players try to discover the location of oil deposits on a map, get control of all the deposits in an oil field, and develop the oil field with producing wells.

Materials

- one gameboard map for each player and the Banker
- $1 000 000 for each player
- money for the Banker to lend the players
- pack of Developer's cards

Rules

1. One person is chosen to be *Banker*. The Banker is not a player. The Banker secretly colors squares on the Banker's Gameboard to mark the location of the oil deposits. (For two or three players, color five or more squares per player. Color fewer squares for more players.) The colored squares must touch on sides or corners, like this:

2. One colored square means one *oil deposit*. A group of colored squares means a group of oil deposits in an *oilfield*. The Banker tells the players how many deposits and oilfields are hidden.
3. The players at this stage are *Drillers*. Drillers take turns trying to locate the oil deposits by guessing where to drill. A Driller names the region to be drilled by letter and number. Dusty Creek, for example, is located at J7. A Driller who locates an oil deposit becomes the owner of the oil deposit.
4. Drillers pay the Banker $50 000 for each turn to drill a test hole.
5. Drillers who run short of exploration money can borrow $500 000 once from the Banker. By the end of the game, the Driller must pay back the loan to the Banker, plus 20% interest ($100 000), for a total of $600 000.
6. A Driller who owns all the deposits in one oilfield becomes a *Developer*. A Developer draws one *Developer Card* during each turn. A Developer can also continue to drill for more oil deposits, as before.
7. Oil deposits may be bought, sold, and traded. The base price for one oil deposit is $250 000, but owners may ask for more.
8. A Developer can get one loan of $1 000 000 from the Banker. The loan must be repaid with interest of 20% ($200 000) at the end of the game.
9. A Developer can set up one producing well in each deposit by paying the Banker $250 000. Banker and Developer mark the location of the well on their maps like this:

   Money will be paid to a Developer for each producing well when a *Dividend Card* is drawn from the Developer's pack.
10. When all the oil deposits have been found, the Banker so informs the players.
11. Players may go through the Developer Cards more than once, if time permits.
12. At the end of the game, players count their money, the value of their property, and repay any loans. One oil deposit, without a well, is worth $250 000. The oil deposit, with a producing well, is worth $500 000.

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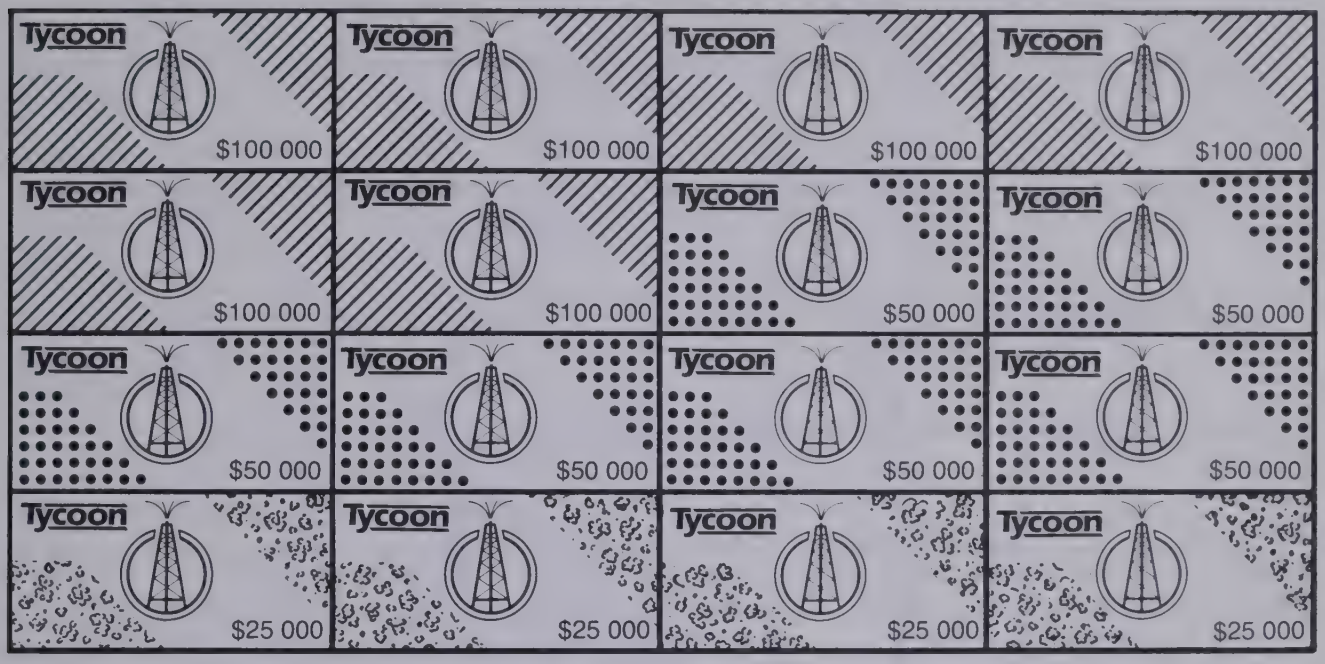

I promise to pay the Bank
$1 000 000 plus 20% interest
of $200 000.
Total: $1 200 000

I promise to pay the Bank
$1 000 000 plus 20% interest
of $200 000.
Total: $1 200 000

I promise to pay the Bank
$1 000 000 plus 20% interest
of $200 000.
Total: $1 200 000

I promise to pay the Bank
$500 000 plus 20% interest of
$100 000.
Total: $600 000

I promise to pay the Bank
$500 000 plus 20% interest of
$100 000.
Total: $600 000

I promise to pay the Bank
$500 000 plus 20% interest of
$100 000.
Total: $600 000

BANK LOAN $1 000 000

BANK LOAN $500 000

BANK LOAN $1 000 000

BANK LOAN $500 000

BANK LOAN $1 000 000

BANK LOAN $500 000

BANK LOAN $1 000 000

BANK LOAN $500 000

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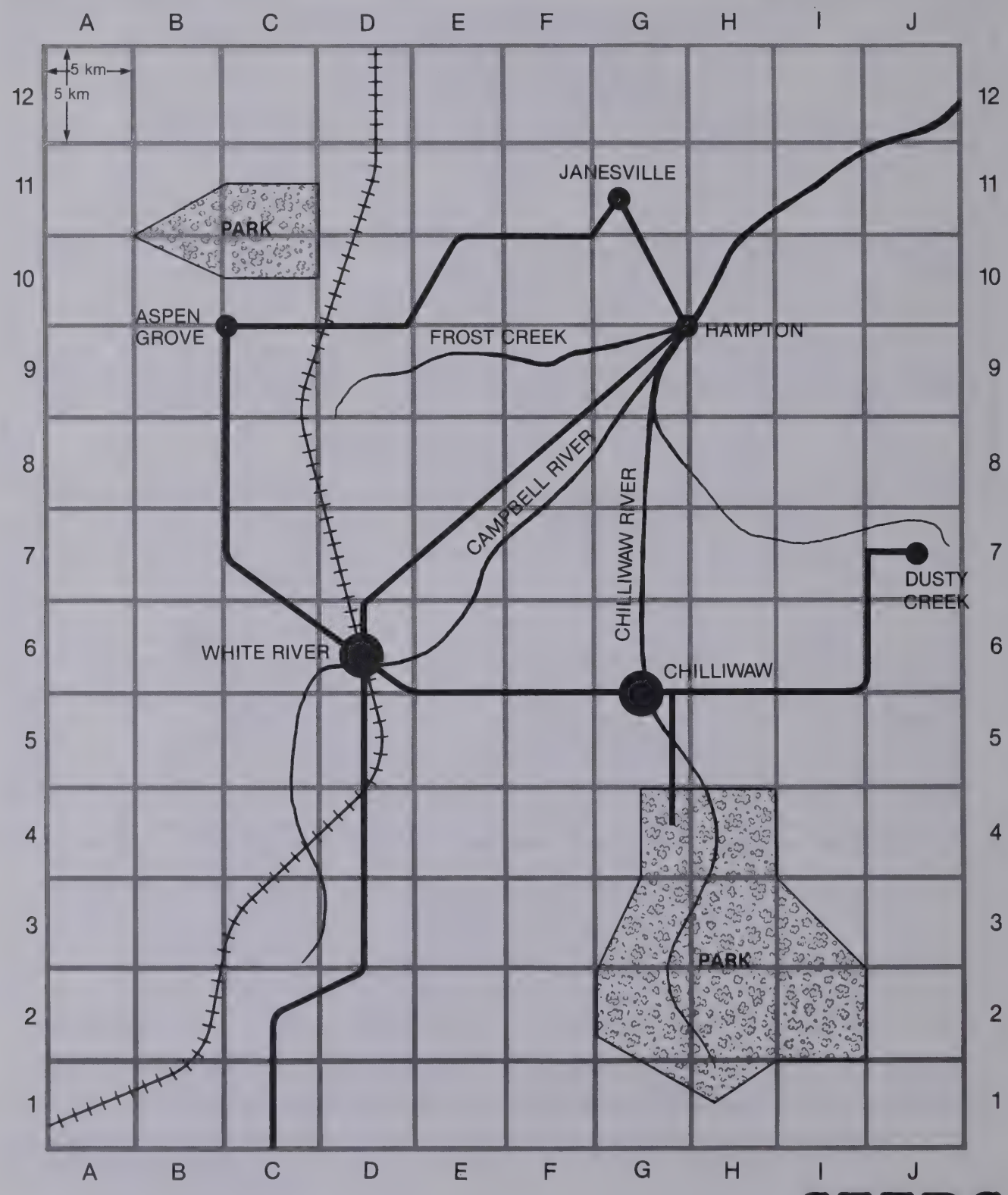

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Nonrenewable Sources of Energy
Exercise Sheet 9D

For use with Chapter 6

Your wells run dry. Too bad. Pay off any loans.	The drill bits arrive late. You lose $25 000. Pay the Banker.	Your wells are all producing. Congratulations! Collect $75 000 for each producing well.
You completed the drilling ahead of schedule. You deserve a bonus. Collect $100 000.	A gusher! Collect $300 000 from the Banker.	The drill core looks promising. Take an extra turn.
Explosion damages the drilling equipment. Repairs cost $200 000.	Your oil is on Indian lands. Before drilling can begin, you must get permission. Miss a turn.	The railroad goes on strike. You can't sell your oil until the trains roll again. Miss a turn.
This is a deep hole. More drilling is needed. Pay out $25 000.	Oil spills cause environmental damage. Pay out $250 000. Miss a turn while the spill is cleaned up.	An accident stops operations for a while. You lose $25 000.
Your deposit is a rich one. You can drill more wells. Collect $500 000.	Hard rock ahead. Drilling costs increase. Pay out $150 000 for each oil deposit you own.	The drill string breaks. While the crew fishes the broken pipe out of the hole, you miss two turns.
Drilling pipe is in short supply. You will have to wait for more to arrive. Miss a turn.	Pay out $100 000 for each oil deposit you own that is within 5 km of a town. Miss a turn while you settle the problems.	Bad weather slows down drilling. Miss a turn.
Bad luck. Very hard rock ahead. Diamond drill bits are needed. Pay out $100 000.	Your wells are producing. Collect $100 000 for each well from the Banker.	Machinery breakdown. Pay out $25 000 for repairs.
If your oil deposit touches a National Park, you must discuss your plans with park officials. Miss two turns.	Your oil company declared a profit. Give yourself a bonus of $250 000.	Buy more drill bits. Pay out $50 000.
The drilling crew goes on strike. You lose $100 000 while you wait. Pay the banker.	Good luck. Layers of soft rock put you ahead of schedule. Take another turn.	Build a road from the nearest railroad line to one of your oil deposits. Pay out $50 000 for each section of road that is 5 km, or less.
Fire damage to the machinery will cost you $75 000.	It's time to declare dividends. Collect $150 000 for each well that is producing.	It's dividend time. Collect $100 000 for each producing well.
Heavy machinery causes pollution and damage to streams. Pay out $150 000 and miss two turns.	Oil prices go up again and so do your profits. Collect $500 000.	

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Nonrenewable Sources of Energy
Exercise Sheet 10

For use with Chapter 6

Compare two of four major sources of energy, coal and petroleum.

	Coal	Petroleum
Origin		
Formation Process		
Location		
Extraction		

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Nonrenewable Sources of Energy
Exercise Sheet 11

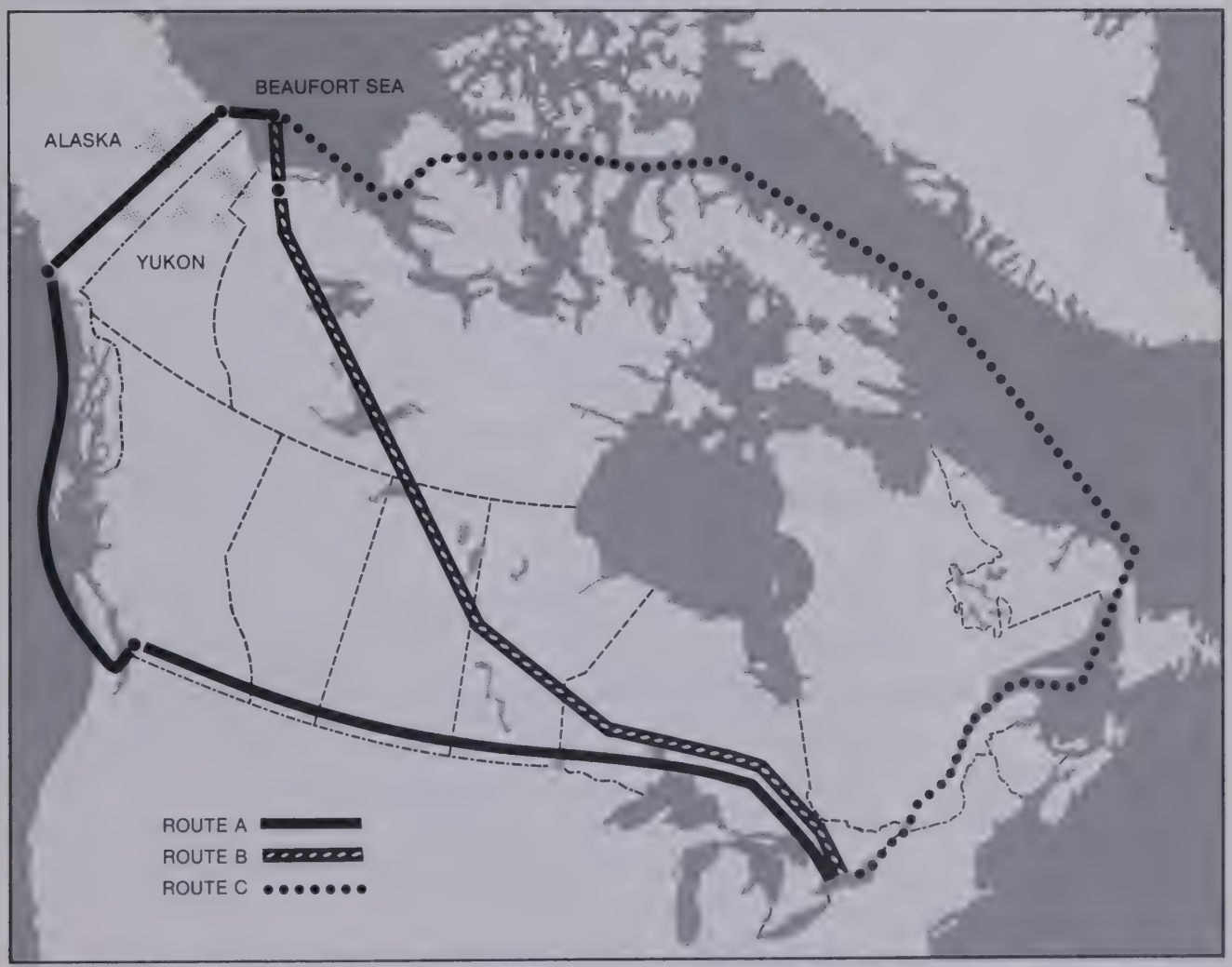
For use with Chapter 6

Assume that large amounts of petroleum have been discovered in the Beaufort Sea. It is your responsibility to choose the best route to the refineries and major markets of Eastern Canada. Three routes are proposed.

Route A From the oil field by pipeline to the shore. By pipeline across tundra and mountains to a seaport. By supertanker down the coast of British Columbia, through the Strait of Juan de Fuca to Vancouver. By pipeline across the Coast Mountains and Rocky Mountains, the prairies and north of Lake Superior to Ontario and Quebec.

Route B From the oil field by pipeline to the shore. By pipeline across tundra and bush country, south and east to Lake Superior, and then to the major refineries of Ontario and Quebec.

Route C From the oil field by supertanker through the Northwest Passage. Then south through the Atlantic Ocean to the St. Lawrence River and the Quebec and Ontario refineries.



Explain the hazards and the advantages of each route. Make a choice and be prepared to defend your choice.

Route A _____ **Route B** _____ **Route C** _____

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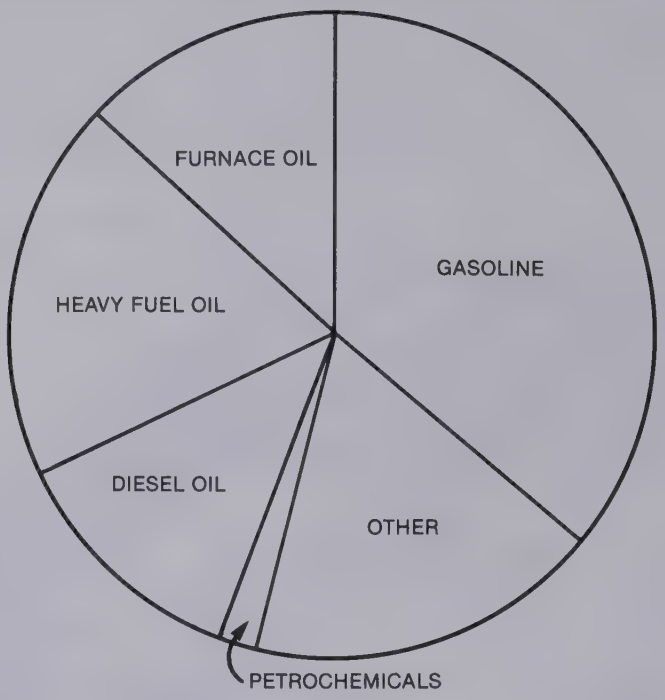
Nonrenewable Sources of Energy
Exercise Sheet 12 — For use with Chapter 7

The circle graph shows the products of crude oil refining in Canada. Find the percentage of crude oil used for each product.



1. Measure each sector of the circle graph in degrees. Enter the measurements, using a protractor, in the chart. Check that the total is 360°.
2. Calculate the percentage for each product.

   $\frac{\text{number of degrees}}{360°} \times 100 =$ _____%.

   Round off your numbers to the nearest whole number. Check that the total is 100%.

	NUMBER OF DEGREES	PERCENTAGE
GASOLINE		
FURNACE OIL		
HEAVY FUEL OIL		
DIESEL OIL		
PETROCHEMICALS		
OTHER		
TOTALS		

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Nonrenewable Sources of Energy
Exercise Sheet 13

For use with Chapter 8

Compute your own radiation dose by filling out this sheet.

	Source of Exposure	Annual Dose (mrem)
Where you live	Cosmic Radiation • Location at sea level • Count 3 for every 150 m above sea level.	41
	Terrestrial (average based on U.S. data – terrestrial variation not definitely known in Canada)	40
	House Construction (based on 18-h day in house) • If wood construction, subtract 8. • For other type of house – do not subtract	
What you eat, drink, and breathe	• Naturally occuring radionuclides • Fallout from previous A-weapon tests	18 4
How you live	• One chest X-ray • One dental X-ray	40 20
Living near a CANDU nuclear station	• If at site boundary, add 2. • If 1.5 km from boundary, add 0.7. • If 8 km from boundary, add 0.1.	
	TOTAL	
	COMPARE WITH NORTH AMERICAN AVERAGE	182

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Nonrenewable Sources of Energy
Exercise Sheet 14

For use with Chapter 10

What is the impact on the environment of the following energy sources? Consider extraction (mining), transportation, and use factors.

ENERGY SOURCE	EFFECTS ON LAND	EFFECTS ON WATER	EFFECTS ON AIR
COAL			
OIL			
NATURAL GAS			
URANIUM			

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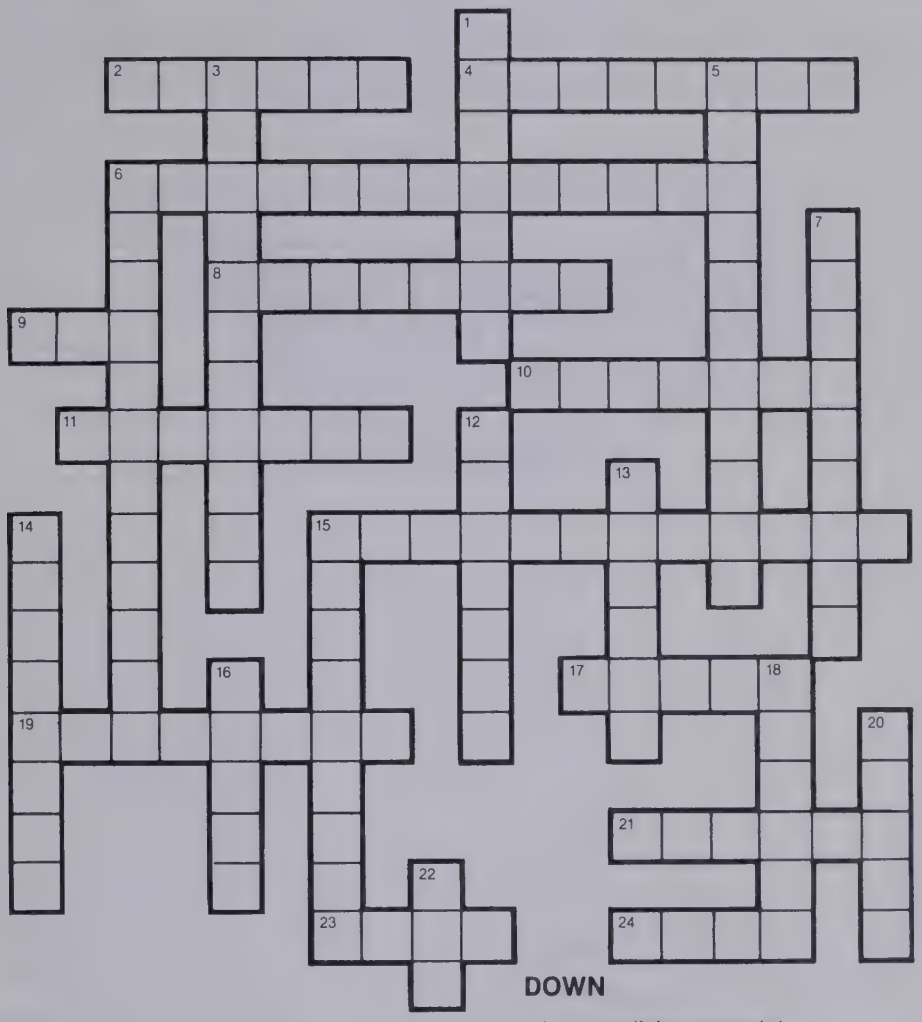
Nonrenewable Sources of Energy
Exercise Sheet 15

For use with Chapter 10



ACROSS

2. means "in place"
4. where crude oil is converted to useful products
6. an arrangement of pipes and valves to control the flow of an oil or gas well
8. the most efficient way to transport large amounts of gas and oil over land
9. a fossil fuel
10. soft coal
11. fuel for CANDU reactors
15. a method of separating liquids that have different boiling points
17. _____ oil
19. type of mine with two parallel tunnels
21. country with the largest single oil-sand deposit
23. natural gas that contains hydrogen sulfide
24. the solid left by the destructive distillation of coal

DOWN

1. once-living material
3. extraction of coal to the surface
5. most of the coal mined in 1980 went to the production of _____
6. saving energy by not wasting
7. *in situ* recovery of bitumen using two wells and a fire
12. the petroleum that is removed from oil sands
13. coal that has been crushed and mixed with water for transportation through a pipeline
14. the fuel with the lowest boiling point: fuel oil, gasoline, or jet fuel
15. earth-moving machines used in strip mining
16. natural gas with the hydrogen sulfide removed
18. the part of natural gas used to make plastics and other synthetic materials
20. layers of coal
22. drilling fluid

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Nonrenewable Sources of Energy
Exercise Sheet 16

For use with Chapter 10

Recycling may be one small way of extending the life of our petroleum supplies. Lubricating oil that goes into a car engine is clear and a golden brown color. When the oil is drained from the engine, it's a muddy gray color. It looks dirty. The "dirt" is tiny particles of metal that have worn away from the engine, plus some carbon and acids from the burned gasoline. All this dirt can now be removed from the oil. Motor oil can be recycled and used in car engines many times.

Petroleum would be conserved if car owners could be persuaded to accept recycled oil. These are the facts:

- Recycled oil is safe to use. (Railways have been using recycled oil in locomotives for thirty years.)
- Recycled oil conserves our crude oil. (One litre of recycled oil saves up to nine litres of imported oil.)

1. Prepare advertising for a magazine page, for radio, or for TV to convince car owners to use recycled oil. Find out from talking to car owners why they might resist buying it.
2. Create advertising to change their minds.

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PROFESSIONAL REFERENCE GUIDE

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Introduction

The SEEDS materials have been designed for use either as an energy unit in a core science/social awareness curriculum or to stand on their own as an energy curriculum. The Teacher's Guides and Teacher's Resource Books of the SEEDS program present strategies and techniques for the *how* of teaching the program's energy literacy concepts and skills. This Professional Reference Guide provides a comprehensive view of the *what* and the *why*. The cross-level content development, the spiral pattern of expanding concepts, the learning/thinking/valuing skills, and the progression and interrelationship of objectives and skills from level to level are summarized in subsequent sections and charts. However, it is important at this point to re-state the original motivation and rationale for the program.

Robert Westbury, Executive Director of the SEEDS Foundation, summarized the history of the Foundation and the development of the Curriculum Project in a brief Preface at the beginning of each Teacher's Guide and Teacher's Resource Book. Two statements bear repeating here: The primary goal of the Foundation—"to encourage the development of an energy-literate society, a society concerned about and committed to the wise use of energy"; and the rationale for the educational modules that comprise the Curriculum Project—"to help young people develop informed views on energy and the environment and act on them."

In the process of preparing the material for publication, Dr. Westbury was intrigued to find that another concerned educator, Rodney F. Allen, had independently compiled the following list of "justifications" for energy education in the booklet, *Energy Education: Goals and Practices*, published by the Phi Delta Kappa Educational Foundation in 1980:

"*Educated Citizenry Justification:* A basic premise of democracy is that citizens with adequate skills and knowledge participate in making the decisions that affect them. Solutions to energy problems require a knowledge of, and participation in, the political process. Traditionally, education has served to equip citizens with the knowledge and skills needed to make such decisions and to take action.

"*Economic Justification:* Energy education is needed so that citizens may make rational choices in their personal lives about public policy questions.

"'*Doing Good*' *Justification:* Energy education offers the opportunity to create a more just and humane society. It can provide the re-educative process that will lead to a more environmentally sound lifestyle and a more equitable distribution of goods and services in the national and world community.

"*Problem-Solving Justification:* Solving widespread energy and environmental problems can be undertaken by a well-educated citizenry. Since energy is so directly related to the conditions that sustain life and give it meaning, educational programs are needed to provide the techniques for solving the energy crisis.

"'*Take Care of Self*' *Justification:* Energy education can teach people how to conserve energy and to make decisions to optimize their personal resources and well-being. Such learning will build personal responsibility and will help to protect personal effects.

"*Educated Person Justification:* Society is beset with technological problems about resource use that require educated and inquiring minds. Energy education should be part of general education now and in the twenty-first century. A sound knowledge of energy concepts and issues should be expected of all educated people

"*Career Education Justification:* Many of today's students will find careers in energy industries (e.g., solar installation, energy audits, and energy-efficient construction) or in industries that depend on crucial energy decisions. Schools have a role in preparing students for these and other careers.

"*Stewardship Justification:* Energy education, like environmental education, offers an opportunity for persons to learn a "common good" ethic, where the well-being of all people (including those yet unborn) is taken seriously in resource use and in the allocation of goods and services. If everything is connected to everything else, we need to learn those relationships and to use them. The welfare of all and responsibility to the posterity of our nation are central themes in this argument.

"*Apocalyptic Justification:* We must learn the wise use of energy resources since there is such a limited supply of nonrenewable energy resources. National survival and the well-being of the world community depend upon effective and equitable use of energy to ward off resource depletion on the one hand and environmental disaster on the other. We need people who can stand at Armageddon and do battle for our survival.

"Whether or not one concurs with all of the justifications offered here for energy education programs in the schools, learning about energy is essential for the social education of all children whose lives will extend well into the twenty-first century. In responding to dwindling energy supplies, our technological advances may be spectacular. Legislation may force us into immediate conservation efforts. Pricing mechanisms may cause lifestyle changes. But in the long run, it is the knowledge, abilities, and personal commitments of the people in a free society that will permit successful responses to the energy crisis."

The Foundation does not claim such all-encompassing justifications for either its own existence or the curriculum materials, but interwoven in its name are the three topics that recur in the descriptions above—Society, Environment, and Energy. The main ideas grouped into these three strands evolved from the preliminary content analysis undertaken by the educators for the preparation of the curriculum materials.

The main ideas provide the broad organizing concepts, drawn from the social sciences, the natural sciences, and the physical sciences, that recur from level to level throughout the program. They are presented within different contexts and with gradually increasing complexity as the students progress. The process of concept-learning is inherent in the specific objectives, stated in terms of learning outcomes expected for the students.

We have used the term "energy literacy" to describe this process designed to lead to the development of informed views on energy and the environment. But the objectives also reflect the behavioral goals of changing one's attitude, of taking action on a personal level and in related social issues, of conserving energy where possible, of wisely *using* rather than *abusing* our natural resources.

Definitions and Concepts

In developing the main concepts from the social, the natural, and the physical sciences, the presentation in the student materials has been written to the level of the average student's understanding. This has, at times, necessitated the simplification of explanations or definitions. For example, the statement "energy is the ability to do work," while satisfying to scientists, is only puzzling for most students. Students can more easily gain an appreciation of the meaning through activities and experiences that broaden their understanding.

For more capable students, more detailed definitions or explanations should not be avoided. But all students should be encouraged to continue testing, exploring, investigating, and discussing observations until they can give a satisfactory explanation in their own words. At that point, the name for a concept or the accepted definition can be provided by the teacher.

For this reason, we have provided some background information for teachers who may not have a full command of the concepts dealt with in the program. These Teacher Background sections are provided to reduce the need for teacher preparation. However, there is no substitute for in-depth teacher preparation and practical investigation since both teachers and students benefit from the processes of investigating, hypothesizing, and testing in order to gain a better understanding of how our world functions. Teachers should be aware that the following topics in particular have been presented in a simplified form in all components of the elementary levels and in increasing detail in the upper levels of the SEEDS program: the definition of energy, the definition of solar energy, the description of energy flow on earth, and the definitions of "renewable" and "nonrenewable" as applied to sources of energy. For teachers who feel that their students can benefit from an earlier technical introduction to these topics, the following essay should prove helpful.

Energy is a quality or state of an object or set of physical circumstances. Energy can be thought of as the source of all activity in the physical world. Physical phenomena represent transformations or exchanges of energy. Thus, the classical definition of energy as "the ability to do work" reflects the difficulty we have in defining it as a concrete, physical entity. We tend to quantify and describe energy in terms of what it can *do* rather than what it *is*.

On earth, our main source of energy is the sun which is a middle-aged star, about four and one-half-billion years old, that has not yet exhausted its hydrogen fuel. Spectral analysis of the sun's light and other astronomical data indicate that about three-quarters of the sun's mass is hydrogen; about 20% or more is helium; and the remainder is composed of traces of elements like carbon, nitrogen, oxygen, magnesium, and silicon.

Using information gained partly by observation and partly by theoretical models, scientists have described the sun as composed of various layers: the *core* where thermonuclear reactions occur; the *convection zone;* the *photosphere* or deepest visible layer; the *reversing layer;* and the *atmosphere*, composed of the *chromosphere* and the *corona*. The atmospheric layers may have temperatures of over 1 000 000°C but the photosphere is only about 6 000°C. From the photosphere inwards, the temperatures, pressures, and density of material increase dramatically. The temperature of the core is about 20 000 000°C. At the temperatures and pressures encountered near the center of the sun, only the most elemental forms of matter can exist — atomic nuclei must be nearly stripped of their electrons. *Plasma* is the term used to describe this "fourth state of matter" which is not solid, liquid, or gas.

The sun is like a gigantic hydrogen bomb generating energy in its core at a prodigious rate. It is believed that two hydrogen nuclei fuse to form one helium nucleus, subsequently releasing

energy in the process. It has been estimated that some 597 000 000 t of hydrogen fuse to form 593 000 000 t of helium every second. Because of the vast quantity of hydrogen present, the sun will continue producing energy at this rate for billions of years. As the hydrogen supply becomes depleted, and the sun's composition becomes less homogeneous, another set of nuclear reactions may cause the sun's luminosity and size to increase so much that the earth will boil away. However, this may occur some four and one-half-billion years hence.

The energy released in the sun's core is transported to the surface by a combination of radiation and convection. *Convection* is the transmission of heat energy by the physical movement of material; *radiation* is the transmission of energy by photons. Radiation dominates in the interior regions and convection in the outer quarter of the sun's radius, terminating just below the photosphere. In the photosphere, radiation takes over completely. The earth's upper atmosphere receives only about one two-billionth of the sun's radiant energy. About 30% of this is reflected back into space. The remaining portion warms our planet, generates the ocean currents, drives the local and global wind and water cycles, and sustains life.

Only about 0.03% of the incident solar radiation is captured and converted into organic matter by green plants through the process of photosynthesis. Much of this material will eventually decay and thus release its stored solar energy. Over the last six hundred million years or so, a very minute fraction of organic matter has been deposited in oxygen-deficient environments and thus has been preserved in the form of fossil fuels—the so-called nonrenewables. Other sun-dependent energy sources, such as wind, water, and biomass, have been classified as the renewables.

The classification scheme for determining whether or not a particular energy source is renewable or nonrenewable depends on how one wishes to interpret the factors considered in the definition, such as the type of source, the amount present, its rate of consumption, and/or rate of formation, as well as the time scale being dealt with. The fossil-fuel stock is being replenished through processes similar to those that created it in the past, yet at about the same rate as in the past. Thus we could argue that the term "nonrenewable" is inappropriate. But, fossil fuels are being consumed at a far greater rate than their present rate of formation. In several centuries, they may not be available for us to use, but several million years from now, they may possibly be available again.

A similar argument can be developed for biomass energy from trees. We can say that trees replace themselves (reproduce) in a relatively short period of time. Thus, they are a renewable energy source. Yet if the rate of consumption outpaces the rate of replacement, this source of energy effectively becomes nonrenewable. Even the most important source of energy, the sun, will eventually "burn up." Thus, the definitions of renewable and nonrenewable, as well as their applicability, tend to become less clear and may even break down under close scrutiny. For the sake of convenience, the terms *renewable* and *nonrenewable* are used to simplify relative comparisons between energy sources for discussion in terms of the everyday world we live in.

All levels of the SEEDS program develop the following major concepts.

1. Our earth is a self-contained life-support system composed of a large number of environments, or ecosystems.

2. All living things fit into a complex pattern of interrelationships and interdependencies.

3. People, as well as all other living things, affect their environment and are in turn affected by it.

4. The sun is the earth's most important source of natural energy.

5. People have in the past freed themselves from a way of life dependent on their own muscle-power and the muscle-power of any animals they were fortunate enough to own by using energy from various sources. Modern civilization, and ultimately life itself, will continue only as long as adequate energy sources are maintained.

6. People must change their ways of living to fit changing conditions.

7. The principle of balance is a key to the understanding and wise use of resources.

8. If a natural environment is undisturbed by human beings, it tends to move to a state of equilibrium, or balance.

9. Human beings must disturb the natural balance in order to satisfy their energy needs. However, they should try to establish a new balance, whenever they can. This new balance should be one that supplies their needs while still maintaining the factors that create the needed resources.

10. Individuals should develop sets of values that balance future needs against immediate gains, and social good against private advantage.

Content Summary Chart

	What Is Energy?	Sources of Energy	Conversion of Energy / Forms of Energy	Concerns for the Environment	Wise Use of Energy
Nonrenewable Sources of Energy	General Description • fuel • food • power	History of Energy Sources in Canada • wood • coal • oil • gas • uranium	Combustion → Heat Fission → Heat Distillation → Fuel + By-products Refining → Fuel + By-products	Coal • mines • leaching • combustion Oil • pipelines • tankers • combustion Uranium • mines • reactor • waste	Comparison of supply and demand curves. Definition of *wants* and *needs*. The case for conservation.
Renewable Sources of Energy	Historical Description • chronology of energy sources	Solar Biomass Wind Tidal Geothermal Hydrogen	Radiation → Heat Conduction → Heat Convection → Heat Distillation → Heat Decomposition → Fuel + By-products Mechanical → Electricity	Solar • esthetic Biomass • esthetic Wind • esthetic Tidal • silting	Identification of the role renewable sources of energy can play in the conservation of energy.
Sources of Electrical Energy	Technical Description • force • work • units of energy (joule and watt)	Electricity, the most useful *form* of energy • from hydroelectric *sources* • from thermal-electric *sources*	Perpetual-motion Machines Mechanical → Electricity Combustion → Heat → Mechanical → Electricity Fission → Heat → Mechanical → Electricity	Coal • mines • leaching • combustion Oil • pipelines • tankers • combustion Uranium • mines • reactor • waste Hydroelectric power • dams • towers and wires	Comparison of statistics for projected supply and demand. Doubling effect. Practical and realistic suggestions.

Core Objectives and Skills

Method of Listing Objectives in SEEDS

The pedagogical goal of the SEEDS program is not only to foster the development of understanding and thinking processes with regard to energy and the environment but also to promote attitudinal learnings that will manifest themselves in positive actions, feelings, and values. Both kinds of objectives—cognitive and attitudinal—are included among those listed at the beginning of each activity in the Teacher's Resource Book.

The objectives are listed in as specific a manner as possible, using concrete verbs such as *demonstrate*, *compare*, *contrast*, *classify*, *explain*, *recognize*, *investigate*, and *examine*. There are several reasons for listing the pedagogical objectives so specifically at the beginning of each activity:

1. A clear statement of objectives can help the teacher to assess whatever skills and knowledge the students may already have.

2. Some of the objectives listings may actually be presented to the students themselves rather than serving as teacher information only. Understanding the objectives of a particular activity can help the students to focus upon the desired outcomes of the activity.

3. The listing of educational objectives can help teachers to plan additional learning experiences in conjunction with particular activities, if they wish to do so.

4. The objectives listings are an important aid in evaluation of the students' learning.

The following pages show the core objectives charted by organizing concept.

Core Concepts	Nonrenewable Sources of Energy	Renewable Sources of Energy	Sources of Electrical Energy
The Nature of Energy	Define energy by some of its many forms Relate activity and motion to energy Describe an atom	Recall the definition of energy Become familiar with the concept of room temperature Recognize some of the relationships among kinetic energy, mechanical energy, and potential energy Demonstrate that it takes 1 J to lift 100 g 1 m Recognize that power is energy divided by time Recognize that power (in watts) is energy (in joules) divided by time (in seconds)	Explain the failure of perpetual-motion machines on scientific principles Explain and use the unit *joule* Convert Calories to joules Explain the term *watt* Explain the term *power* Convert horsepower to watts
The Importance of Energy from the Sun	Explain how the sun is the source of most of the earth's energy Relate the process by which the sun's energy was converted into the fossil fuel we know as coal	Recall previously-held views of the sun and compare them with modern views of the sun Recall facts about temperature and state of matter in the sun Explain how the sun works Explain how much energy the sun produces	
Sources of Energy	Explain why fuel sources in Canada were first wood, then coal, then petroleum Explain why coal is called a fossil fuel Explain why not all types of coal have the same composition and how this affects fuel quality Explain the theory of the formation of petroleum Explain the difference between uranium and stable materials Tell the story of the uranium cycle from exploration to nuclear reactor	Define solar energy Express the amount of solar energy the earth receives Recall that the earth turns from east to west Recognize that warm air rises and has low pressure Recognize that cool air falls and has high pressure Recognize that high-pressure air moves toward low-pressure air Show that uneven heating of the earth's surface by the sun causes wind Recognize that wind has kinetic energy	Explain the reason for the tides

	Nonrenewable Sources of Energy	Renewable Sources of Energy	Sources of Electrical Energy
Distribution and Extraction of Energy Sources	Explain how coal lying near the surface is mined Explain how coal lying far below the surface is mined Explain what happens to raw coal to prepare it for the buyer Locate the coal resources in Canada Explain how petroleum deposits are located by seismic survey Explain how petroleum deposits are reached and how petroleum is brought to the surface Explain how petroleum deposits that lie under the ocean are reached Describe the nature and extent of the oil-sands deposits in Alberta Describe the processes used to mine oil sands Explain how synthetic crude oil is extracted from oil sands Investigate methods of transporting oil from offshore-drilling rigs Explain how oil is transported from the well to the refinery over land and across water Recognize how uranium deposits are located	Discuss problems with capturing the sun's energy Become familiar with a radiometer Demonstrate that the angle of a source of radiant energy to the vanes of a radiometer affects the speed at which the vanes revolve Demonstrate that when the inside of a container is heated by the rays of the sun, the type of cover on the container affects the change in temperature Become familiar with the idea that black surfaces absorb the sun's energy better than white surfaces Demonstrate that when a container is heated by a source of radiant energy placed outside it, the material inside the container affects the change of temperature Recognize that walls and floors absorb energy and radiate it back Become familiar with how solar collectors work Explain how photovoltaic collectors work and how silicon cells are made Recognize how biomass is grown for fuel List some of the components of a horizontal-axis windmill Demonstrate that the angles of the blades of a windmill affect the speed at which the vanes of the windmill revolve Demonstrate that a windmill can be used to store wind energy List four types of horizontal-axis windmills	Explain simply how uranium is extracted and refined List the conditions needed for a hydroelectric site Explain the principle behind a greenhouse Explain how wind energy can be exploited by a wind generator Explain why direct current and storage patterns are associated with wind generators Explain how tides could be exploited for electrical energy in the Bay of Fundy Explain how solar cells could be a source of electrical energy on a large scale Explain how much electrical energy could be produced from our forests Explain what geothermal power is and how relevant it is for Canada Explain what is meant by small-scale hydro

		List three types of vertical-axis windmills State three types of energy storage used by windmills Become familiar with an anemometer Become familiar with the Beaufort scale of winds Rate windspeeds as suitable or unsuitable for windmills	
Energy Conversion	List some of the many by-products from the destructive distillation of coal Explain what distillation means Explain how the principle of distillation can be used to separate liquids with varying condensation temperatures Give a simple explanation of fission Explain how electricity can be produced from uranium	Describe how silicon cells turn the sun's energy into electricity Demonstrate that oxygen helps wood to burn Demonstrate that an aquatic plant exposed to sunlight gives off oxygen Observe and become familiar with dry, or destructive, distillation Recognize the fuels and by-products that can be obtained from biomass Recognize some characteristics of biomass by-products (charcoal, tar, alcohol, and methane) Demonstrate that energy is stored in biomass and that the stored energy can be released by burning the biomass Demonstrate that the energy released from burning biomass can be used to raise the temperature of water Recognize how fuels can be obtained from biomass Find out how much energy (in joules) a model windmill can generate Find out how much power (in watts) a model windmill can generate State the parts of a windmill that make electricity	Describe simple conversions of energy and describe the output of the conversion Give examples of static electricity Connect a simple electric circuit and trace the path of the electricity in that circuit Identify conductors and insulators Show that electricity produces magnetism Show the principle of the electric generator: that an electric current can be produced by coils of wire and magnets Identify the key parts of a generator Explain what a turbine is and how it works Explain how the energy of falling water can be converted into electricity Explain how water stored behind a dam is used to produce electricity Explain how electricity is produced in a thermal-electric plant, whether the fuel is coal, oil, or natural gas Explain fission in simple terms Explain how electricity can be produced from uranium

	Nonrenewable Sources of Energy	Renewable Sources of Energy	Sources of Electrical Energy
Uses of Energy and Energy Sources	Define energy by some of its many uses Fit the present widespread use of petroleum for heating and transportation into a historical time frame Account for the changes in the use of coal from 1950 to 1980 Explain how coal is used in the production of steel and electricity Learn that the refinery turns crude-oil fractions from the fractionating tower into more than 1000 different products Learn that natural gas will provide heat, fuel, and the raw material for products in the petrochemical industry Relate the use of petroleum as a source of energy to the larger picture of human history Relate the use of uranium as a source of energy to the larger picture of human history Recall the change in sources of energy used through the centuries	Describe the operation of active and passive solar heating systems State some of the uses of photovoltaic collectors State the fuels that can be obtained from biomass Recognize how biomass can be used for fuels Describe some of the uses of biomass	List ways in which electricity has been applied to home and industry within the past one hundred years Explain why an adequate and continuing supply of electricity is considered to be necessary
Environmental Effects of Extraction, Development, Conversion, and Use of Energy Sources	List some of the hazards of underground mining Explain the effect strip mining can have on the environment Explain the effect underground mining can have on the environment Explain how a planned reclamation can offset the worst effects of strip mining Explain the effect oil-sands extraction has on the environment Explain why oil is spilled on land or on water Explain why oil spills can be damaging to the land and sea environment	List the environmental advantages and disadvantages in capturing solar energy Investigate the consequences of growing biomass for fuel Explain what is meant by the Greenhouse Effect List the environmental advantages and disadvantages in using solar energy Investigate the environmental consequences of using wind energy	List the environmental effects of hydroelectric-generating systems List the environmental effects of thermal-electric generating plants List the environmental effects of the hydroelectric-generating system List the environmental effects of burning fossil fuels in thermal-electric generating plants Explain what is meant by the Greenhouse Effect

	Explain what eventually happens to organic materials, such as oil Name the harmful by-products from the burning of coal and other fossil fuels Explain how acid rain is formed Test the known effects of acid rain List some of the efforts being considered by industry and government to overcome the problem of acid rain Identify the regions in North America most likely to show the effects of acid rain List the advantages of producing electricity by nuclear reactor, and the disadvantages Explain the environmental effects of use of coal, oil, natural gas, and uranium		
Wise Use of Energy and Natural Resources	List some of the beneficial ways radioactivity is being used Describe what effects changes in the future use of coal will have Discuss alternatives to solve the problem of petroleum shortages Recognize new ways in which uranium could be used Explain the benefits of coal, oil, natural gas, and uranium	Give opinions about the role of renewables in our energy crisis Recognize how houses are best situated on building sites in order to use solar energy Explain how biomass from wastes can be used	List advantages the hydroelectric-generating system has over other generating systems Explain why the demand for electricity varies and how the hydroelectric plant can be flexible List advantages of thermal-electric generating plants Explain the meaning of the terms *blackout* and *brownout* Identify ways in which changes could be made by business and industry to conserve electricity Identify ways in which to conserve electricity personally Explain the advantages of small-scale hydro Apply what has been learned about the production of electrical energy to the task of choosing a plan for the provision of electrical energy in the future and weighing the consequences of the plan

The Cognitive Objectives

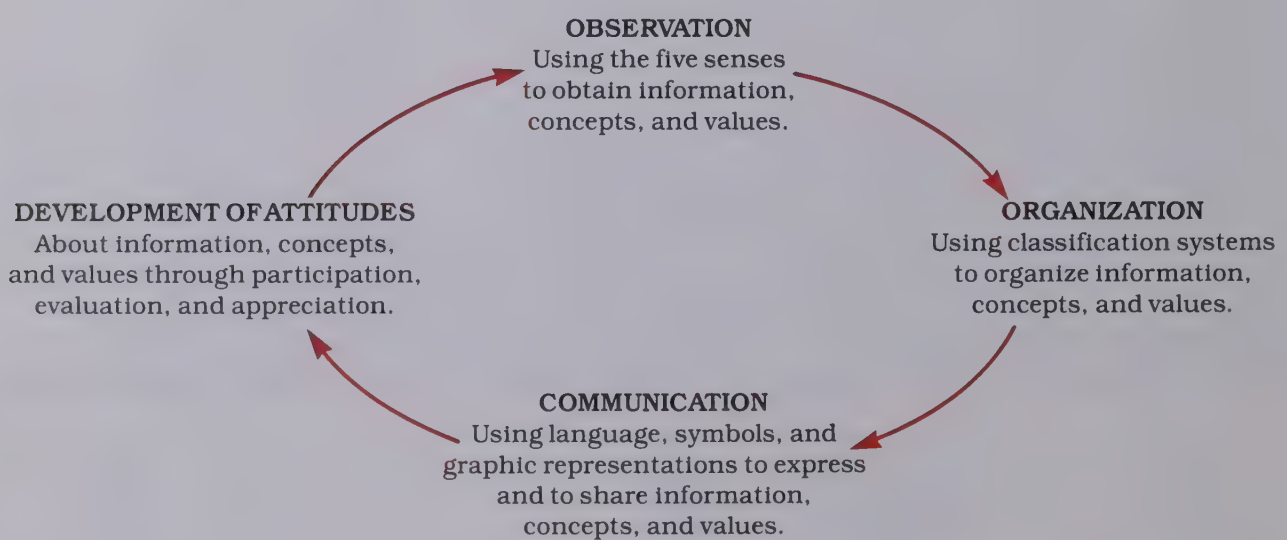
The developers of the SEEDS program have planned the series to assist students in applying rational and scientific thinking processes to energy facts and issues as we know them today. However, it is also hoped that the concepts and thinking skills gained through the series may serve as a springboard for the students in acquiring new energy knowledge and in attacking new energy problems in the future. In our rapidly changing world, students must learn *how to learn*. In order to be effective, well-adjusted members of society, they will need to become lifelong learners.

The following is a partial listing of important thinking and learning skills developed in these levels of the SEEDS program.

- Observing data carefully and accurately.
- Understanding cause and effect relationships.
- Seeing similarities and differences.
- Following order of events; understanding processes.
- Measuring.
- Collecting and organizing information with a specific purpose in mind.
- Making inferences.
- Drawing conclusions.
- Predicting outcomes.
- Evaluating information, ideas, and opinions.
- Finding evidence or proof.
- Reorganizing information into new configurations.
- Presenting information and ideas in clear accurate language, both spoken and written.
- Presenting information in pictorial or graphic form.
- Formulating plans.

Some of the cognitive skills developed in these levels are reflected in the objectives listings found at the beginning of each section of teaching notes in the Teacher's Guides and Teacher's Resource Books. Others, though not specifically listed, can be drawn from the activities themselves to suit individual classes. While there is an emphasis on direct perception of data through observing, listening, and doing, the broader-category skills such as classifying quantities of data, making inferences, and reorganizing information also receive emphasis in these levels.

As the following chart shows, the main learning, thinking, and valuing skills form a circle, each leading to the next. The skills charts on the following pages are organized under these main skills. Specific process skills are charted separately.


OBSERVATION
Using the five senses to obtain information, concepts, and values.
ORGANIZATION
Using classification systems to organize information, concepts, and values.
COMMUNICATION
Using language, symbols, and graphic representations to express and to share information, concepts, and values.
DEVELOPMENT OF ATTITUDES
About information, concepts, and values through participation, evaluation, and appreciation.

Learning, Thinking, and Valuing Skills

Nonrenewable Sources of Energy Renewable Sources of Energy Sources of Electrical Energy

C indicates Core Activity + Student Book page number
X indicates Extension Activity + Teacher's Resource Book page number
E indicates Exercise Sheet + Exercise Sheet number

GENERAL CATEGORIES	SPECIFIC SKILLS	Nonrenewable Sources of Energy	Renewable Sources of Energy	Sources of Electrical Energy
OBSERVATION using the five senses to obtain information, concepts, and values	By studying pictorial representations	All C activities Some X activities Some Exercise Sheets	All C activities Some X activities Some Exercise Sheets	All C activities Some X activities Some Exercise Sheets
	By participating in physical activity (roleplaying, manipulating objects, doing experiments, . . .)	C8, C10, C11, C12, C13, C18, C25, C28, C29, C30, C35, C38, C43, C50, C51, C56	C15, C16, C18, C19, C21, C22, C23, C25, C33, C34, C36, C37, C39, C40, C52, C53, C54, C55 X18, X21	C10, C12, C14, C15, C17, C19, C20, C22, C24, C26, C36
	By observing data carefully and accurately (in naturally occurring situations, classroom demonstrations, experiments, . . .)	C8, C10, C11, C12, C13, C18, C25, C28, C29, C30, C35, C38, C43, C50, C51, C56	C15, C16, C18, C19, C21, C22, C23, C33, C34, C36, C37, C40, C53, C54	C10, C12, C14, C15, C17, C19, C20, C22, C24, C26, C37
	By recalling relevant personal experiences and observations	E13	C8 X18	C49, C63 E1
	By reading	All C activities Most X activities All Exercise Sheets	All C activities All X activities All Exercise Sheets	All C activities All X activities All Exercise Sheets
	By doing research	X10, X13, X18, X32, X36, X42	X9, X20, X21, X30, X37 E1, E3, E4	X20, X34, X39, X44
ORGANIZATION using classification systems to organize information, concepts, values	By recognizing similarities and differences: by making comparisons	C8, C30, C32 E10	C11, C12, C13	E3

	By recognizing cause-and-effect relationships	C7, C18, C21, C22, C27, C28, C30, C35, C38, C50, C51	C17, C20, C22, C23, C24, C25, C26, C27, C28, C29, C30, C48, C49, C50, C51, C53, C55	C10, C12, C14, C15, C17, C19, C20, C22, C24, C26
	By following sequence of events: by recognizing processes	C19, C25, C35, C38, C43	C15, C16, C18, C19, C21, C22, C23, C48, C49, C50, C51	C10, C12, C14, C15, C17, C19, C20, C22, C24, C26
	By classifying information under main headings or in categories	C32 E1, E10		E3
	By classifying information to show similarities and differences	C32 E1, E7		E3
	By recognizing symbolic representations and models	C35, C38, C50, C56	C31, C32, C48, C51, C52, C59	C17, C24
	By drawing conclusions	C8, C9, C10, C11, C12, C13, C18, C19, C25, C28, C29, C30, C31, C35, C38, C43, C50, C51	C17, C19, C22, C26, C34, C37, C40, C50, C51, C53, C55 X19 E1	C10, C12, C14, C15, C17, C19, C20, C22, C24, C26, C37
	By developing key concepts and appropriate corresponding vocabulary	C9, C14, C15, C16, C17, C18, C19, C20, C21, C22, C25, C28, C32, C35, C38, C43, C54, C56, C57	C11, C12, C13, C29, C31, C32, C42, C43, C44, C45, C46, C48, C49, C50, C51, C52, C53, C54, C55	All C activities
	By measuring	C7, C28, C29, C30, C33 E12	C15, C19, C23, C40	C10, C24, C50
	By making calculations	C33, C38, C43 X32 E3, E5, E12, E13	C25, C38, C39, C40, C51 X28 E1, E2	C10, C12, C50, C51, C52, C59, C63 E3, E4, E7
	By drawing on previous personal experiences and observations in order to make inferences	C7, C8, C9, C10, C11, C12, C18, C19	C8, C51, X30 E3	C63 X11

	By speculating about or inferring probable reasons	C7, C8, C9, C10, C11, C12, C18, C19, C35, C38, C43, C50, C51	C8, C17, C20, C22, C23, C24, C25, C33, C36, C39, C51, C57, C58, C59 X30	C10, C12, C54
	By speculating about or inferring probable cause/effect relationships	C7, C8, C9, C10, C11, C12, C18, C19, C35, C38, C43, C50, C51, C54	C8, C17, C20, C22, C23, C24, C25, C33, C36, C39, C51, C57, C58, C59	C10, C12, C40, C54
	By speculating or making inferences about sequences of events: processes	C18, C19 E4	C8, C51, C57, C58, C59	C63
	By making inferences based on and including (hypothetical) situations	C25, C28, C29, C30	C8, C15, C18, C21, C34, C38, C41, C51, C57 C58, C59	C54, C63 X24 E3, E6
	By speculating about meanings of unfamiliar words	C9		C40
	By predicting probable sequence of events	C7, C53, C60, C62, C63	C24, C57, C58, C59	C24, C63
	By predicting probable outcomes, effects, and/or results	C7, C53, C60, C62, C63 E4	C15, C18, C21, C24, C57, C58, C59 X30	C40
	By proposing appropriate actions based on prediction of outcome	C31, C53, C60, C62, C63	C8 X21, X30	C40 E3
	By predicting possible future developments (in society, . . .)	C7, C53, C60, C62, C63	C8 X21, X30	C40, C63 X11
COMMUNICATION using language, symbols, graphic representations to express and share information, concepts, and values with others	By using oral language in informal discussion	All C activities Most X activities	All C activities Most X activities	All C activities Most X activities
	By using oral language in formal interviews, meetings, speeches, papers	X10, X18, X36	X21	X11, X26

	By completing and/or making charts, diagrams, and graphs	C13 E2, E12, E13	C15, C17, C19, C21, C23, C37, C38, C40, C41, C53	C14, C16, C17, C44, C52 X40 E4
	By indicating and/or interpreting features on a map	E4, E11	E6	C39, C40, C57, C58 X34
	By constructing representational models	C35, C39, C50	C52, C59	C24, C26, C36 X11
	By using written language	All C activities Most X activities Most Exercise Sheets	All C activities Most X activities All Exercise Sheets	All C activities Most X activities All Exercise Sheets
	By preparing oral and/or written summaries, reports, paragraphs, . . .	X10, X13, X18, X36	X9, X11, X30, X37, X41, X42 E2	C63 X11, X26, X34, X39, X40, X43
DEVELOPMENT OF ATTITUDES about information, concepts and values through evaluation, participation, and appreciation	By proposing appropriate actions and solutions (social and values issues)	C21, C60, C62, C63 X23, X36, X41	C62, C63 X11, X21, X30, X41, X42	C27-33, C63 X12, X20, X40, X43
	By evaluating actions and solutions (social and values issues)	C21, C22, C59, C60, C62, C63 X23, X36, X41 E1	C62, C63 X11, X21, X30, X41, X42	C27-33, C63 X12, X20, X40, X43
	By judging worth of consequences	C22, C59, C60, C62, C63 X23, X36, X41	C62, C63 X11, X21, X30, X41, X42	C27-33, C63 X12, X20, X40, X43
	By creating a plan of action	C63 X36, X41 E8	C62, C63 X11, X21, X30, X41, X42	C63 X40, X43
	By applying a plan of action	C63 X36, X41 E8	C63 X41	C63 X40, X43
	By participating in group activities (projects, experiments, meetings, games, . . .)	C63 X18, X23, X36, X41 E8	C15-23, C33-41 X11, X30, X33, X41	C63 X40, X43
	By recognizing personal responsibility	C31, C63 X23, X36, X41	X41, X42	C63 X40, X43

Process Skills Chart C indicates Core Activity/X indicates Extension Activity/E indicates Exercise Sheet

Process Skill	Nonrenewable Sources of Energy	Renewable Sources of Energy	Sources of Electrical Energy
Observing	C8, C10, C11, C12, C13, C18, C25, C28, C29, C30	C15, C17, C19, C22, C34, C36, C40, C53, C54	C10, C12, C14, C15, C17, C19, C20, C22, C24, C26
Classifying	C12, C13, C25, C28, C29 E1		
Quantifying	C7, C28, C29, C30, C33	C15, C19, C23, C40, C53, C54	C10, C24
Communicating	X10, X13, X18, X23, X36	C14-23, C33-41	C37 X12 E6
Inferring and Predicting	C7, C53 E3, E4	C57, C58, C59, C61 X30	C24, C37 E6
Formulating hypotheses	C25, C28, C29, C30	C37, C57, C58, C59, C61	X24 E3, E6
Defining terms	C13, C25, C28, C29, C30, C56	C12, C41	E6
Controlling variables	C13, C18, C25, C29, C30, C35, C38, C45	C39, C53, C54, C57, C58, C59	C10, C15, C16, C17, C19, C20, C21, C24, C26, C36 X24
Interpreting data and results	C7, C8, C10, C11, C12, C13, C23, C25, C28, C29, C30, C35, C38, C43, C53, C60, C62 E13	C9, C10, C11, C12, C15, C17, C19, C23, C24-30, C34, C37, C40, C51, C53, C55, C57, C58, C59, C61	C40, C50, C51, C52, C59, C63 E4, E8
Formulating models, plans	C30, C35, C38	C8, C9, C37, C52-53, C57, C58, C59	C17, C24, C26, C37 E5, E6
Processing data	C7, C12, C13, C23, C25, C28, C29, C30, C53, C60, C62 E3, E4, E5	C9, C10, C11, C12, C15, C17, C19, C23, C26, C34, C37, C40, C51, C53, C55, C61	C29, C30, C33, C50, C51, C52, C59, C63 E4, E5
Identifying problems and Seeking further evidence	Most C activities Most X activities	Most C activities Most X activities	Most C activities Most X activities
Applying discovered knowledge	C59, C60, C62, C63 E15, E16	C24, C25, C34, C37, C39, C40, C41, C43, C53, C55	C10, C12, C29, C30, C33, C35, C37, C40, C57, C58, C59, C60, C61, C62, C63 X26

The Attitudinal Objectives

An attitude may be defined as a predisposition to act in a certain way with regard to objects, persons, and ideas. Attitudes are, of course, related to knowledge. However, they also have a connection with emotions and feelings. The goal of the education system is not to induce all students to adopt exactly the same set of attitudes and values. Rather, it is to help students understand the sources of their values and attitudes, to alert them and to encourage them to act and behave in accordance with their chosen attitudes and values.

With specific reference to energy and environmental education, the SEEDS program attempts to cultivate the following positive attitudes and values.

- Being concerned for other people for the common good.
- Recognizing one's personal responsibility to the society in which one lives.
- Recognizing one's responsibility for one's environment, and attempting to live in harmony with that environment.
- Conserving energy, natural resources, and manufactured products; avoiding waste of any kind as a matter of principle.
- Recognizing the complexity of energy issues and maintaining an open mind with regard to differing viewpoints and new information that one may encounter in the future.

An attitudinal objective in the SEEDS program is usually linked with an opportunity for the students to exhibit behaviors and/or carry out practical actions arising naturally from that objective.

Integrating SEEDS with the Core Curriculum

Relationship of SEEDS to Science, Social Studies, and other Subject Areas

By their very nature, the topics of energy and the environment relate to almost everything we do. Thus, in one sense, the teaching of energy literacy and environmental studies should be thought of as an integral part of the curriculum—to be drawn in whenever appropriate no matter what subject area is officially being considered.

However, in practical terms, following this approach exclusively often results in a somewhat fragmented treatment characterized by serious omissions and undesirable overlaps from one level to another. The SEEDS program, with its comprehensive scope and carefully planned progression of learning experiences, provides a solid foundation and focus for effective energy and environment education as part of a science/social awareness curriculum or on its own as an independent energy curriculum.

The SEEDS program is essentially an interdisciplinary one. In the post-elementary levels, the most prominent subject area identified within it is science/social awareness. The scientific and social aspects of energy and environment issues are closely linked. A serious consideration of these issues requires the information, skills, and attitudes taught in both disciplines.

The practice of centering learning on particular problems—drawing in data and skills from a wide range of disciplines as needed—is widely accepted in educational circles today. The SEEDS program, while drawing most heavily on the subject areas of science and social studies, also brings to bear knowledge and skills from a wide range of other disciplines, including language arts, mathematics, health education, music and art. These other disciplines are integrated in various ways within the Core and Extensions.

Practical Suggestions on Scheduling and Timetables

Each school, and even each class within a school, is different in interests, background, and specific learning needs. It is therefore inappropriate to be prescriptive about the way in which the SEEDS program can best be incorporated into the schedule. However, the program is designed to provide approximately four to six weeks of study.

With regard to timetable adjustments for particular classes, the suggestions given here for activities cannot be prescriptive since situations vary so greatly. As a rule, it is probably best to schedule a definite amount of time per day or week for the SEEDS program, while still allowing for some flexibility, if possible. If the actual amount of time remains flexible, the students will almost always have the satisfaction of completing investigations or projects without being interrupted. Sometimes a longer period can be crucial to the gaining of a particular concept or insight.

At the beginning of each activity in the SEEDS Teacher's Resource Book, the teacher is informed of the length of time likely to be required not only by the setting up but also by the duration of the activity. Generally, the time suggested for Activities increases gradually from level to level within the series.

The following are some overall considerations and principles that administrators and teachers may wish to keep in mind as they plan their timetables with reference to the SEEDS series.

1. One possibility for the SEEDS program is that it be scheduled for periods usually given to science and social studies. The time of day is not crucial in many cases.

2. The SEEDS program does not require much use of special rooms or special facilities within the school. Since an average science classroom with the usual equipment will suffice for most of the activities at the upper levels, the need for complicated meshing of schedules among teachers is kept to a minimum.

3. In some cases it may be helpful to appoint a SEEDS program coordinator for the school. (Such a person could not only assist teachers in planning timetables, but could also perform such valuable services as investigating local community problems and resources with regard to energy and the environment.)

4. Team teaching of the SEEDS program or parts of it may be worth considering as a possibility. In this way teachers with special knowledge and capabilities in the area of energy and environment education could share their expertise with more than one class within the school. Science and social studies teachers could profit from a combined approach to the energy issues.

Teaching Strategies Used to Present and Develop Concepts

The "Guided Discovery" Approach

Some science and social studies curricula strongly emphasize processes of inquiry such as observing, describing, measuring, classifying, inferring, and predicting. Others are based on the idea that science and social studies are essentially organized bodies of subject matter. In actual fact, both *processes* and *subject matter* are important. There is a place in the study of science and social studies for both experimentation and reading. Students cannot learn everything from experimentation and firsthand experience. On the other hand, it is important for students to practice processes of inquiry and develop the attitudes of scientifically-minded persons. Scientific processes and attitudes can be transferred to other subject areas, and are valuable as a basis for learning of any kind.

The SEEDS program uses both "telling" and discovery as strategies for the presentation and development of concepts—the "guided discovery" approach. The strategy used in a particular core depends upon such factors as the subject matter under consideration, the probable availability of suitable equipment, and the relative maturity of the students. However, there is in general a stronger emphasis on the discovery approach. It should also be noted that the "discovery approach" may take either an *inductive* or a *deductive* form.

In the inductive form or pattern of discovery, students might make certain observations, form hypotheses based on these observations, and then experiment to test the validity of their hypotheses. In the deductive form, on the other hand, the students might be presented with a generalization first (rather than with a set of observations). They would deduce certain consequences from this generalization. Then they would conduct a suitable experiment and compare its results with the consequences that they had previously deduced. Students might also suggest experiments themselves, following similar methods of investigation.

The following are some practical guidelines for the classroom implementation of the experiments, demonstrations, investigations, and other "guided discovery" experiences suggested in the SEEDS program.

1. As far as possible, allow the students to plan and organize the experiments, making their own predictions about what might happen and drawing their own conclusions about the results.

2. Keep experiments and demonstrations simple. Most of the materials suggested in the SEEDS Teacher's Resource Books are readily obtainable at home or at school. Teachers and/or students should have little difficulty assembling the required materials.

3. Make sure that the students keep the purpose of an experiment firmly in mind as they are conducting it. It may sometimes be advisable to write the purpose on the board for ready reference.

4. It is often helpful to have the students keep a written record, a graph, or a chart of the experiment as it is being conducted. Small drawings of things being observed are also a good way to record information.

5. Whenever possible, allow the students to manipulate the apparatus themselves, even if they only repeat the experiment or demonstration after you have done it once.

6. Take advantage of situations in which experiments do not follow predicted paths. If this happens, a *real* problem has arisen. It is not in any sense a "staged" problem. As a result, the students are challenged to think more deeply and plan more wisely. Thus, greater learning may actually take place.

7. Guide the students to apply information gained from experimentation to real-life situations. Your own local situation will suggest ways of doing this.

8. In your preparation for teaching a particular SEEDS chapter, you may wish to carry out a "dry run" of any experiments and demonstrations connected with the chapter. In this way you can solve any unforeseen problems beforehand. You might like to involve older students who would be interested in helping you do this.

9. You may wish to consider the possibility of filming or video-taping some of the experiments and demonstrations. Students may be interested in making films of themselves performing experiments. Such films could be shown to other classes or to parents on a "parents' day" at school.

Questioning and Class Discussion

Skilful questioning plays an important part in the development of concepts and cognitive skills in the SEEDS program. The following are some of the characteristics of the suggested questions for students found within the Student Book and Teacher's Resource Book.

1. The questions are clear and specific.

2. They are arranged in carefully planned sequences. They are not asked at random, but in integrated series in order to accomplish specific purposes. Sometimes the purpose of a question series is to refine the students' understanding of certain concepts. Sometimes the goal is to identify and/or review important facts. At other times the purpose of the questioning is to have students apply their knowledge to real or hypothetical problems.

3. There is a balance between fact-oriented questions and questions requiring thoughtful answers. Questions requiring thoughtful answers in the SEEDS program encourage the students to use a variety of cognitive processes, including:

- recalling data;
- classifying data;
- comparing and contrasting data;
- showing cause and effect relationships;
- giving examples and illustrations;
- making and evaluating decisions; and
- analyzing or synthesizing facts.

Group Activities

Many of the learning experiences suggested for the SEEDS program involve the students working in groups. This is especially true of the Extension activities that follow the basic Core material. Small-group activity may sometimes be more difficult to organize and oversee than whole-class instructions. However, group work does have certain distinct advantages:

1. Group activities give students a measure of self-determination and freedom.

2. The development of critical thinking is encouraged by group work. The group must propose various courses of action, rejecting some and choosing others.

3. Working in groups develops the students' organizational abilities.

4. The students practice communication skills, and become aware of effective group processes.

5. Group work fosters a spirit of active cooperation, in which a common goal and group welfare are both perceived as important.

6. Students gain new insights into the talents and abilities of their classmates.

7. Group work is a strategy for making learning more meaningful and immediate, since a group project usually involves the application or transfer of learning that has previously taken place.

Community-based Activities

Two obvious ways of making use of community resources are: inviting visitors from the community to give talks or demonstrations, and taking the students on field trips into the community.

Your school may already have a list of suitable resource persons with differing areas of expertise. Sometimes the students themselves may be able to suggest names of possible visitors. Keep the following suggested guidelines in mind when arranging for a visit by a resource person.

1. Find out ahead of time what specific contribution the visitor can make.

2. Discuss with the visitor your reasons for inviting him or her, the grade level of the students and a time that would be mutually convenient. It might be wise to suggest to the visitor approximately how long you would like his or her presentation to take.

3. Make sure that the students have the purpose of the visit clearly in mind ahead of time.

4. Make plans with the students regarding how they can get the most out of the visit. It is often helpful to discuss what kinds of questions they might want to ask.

5. After the visit, discuss with the students what they gained from it. Clear up any misconceptions that they may have.

6. Arrange with the students how they may thank the visitor. An individual or group might be appointed to write a short thank-you note. The class might send the visitor projects or class presentations made as a result of the visit. If appropriate, you or one of the students might even telephone the visitor to thank him or her.

The following suggestions should help you to plan interesting, valuable and trouble-free field trips.

1. Have a real reason for making the trip. The trip should be an integral part of the ongoing study, and its purpose should be clearly understood by the students.

2. Make a "dry run" of the trip yourself first in order to determine realistic objectives and identify any problems that could arise.

3. Make the necessary arrangements with: school authorities, owners or authorities in places you intend to visit, parents (secure written consent from parent or guardian for each student), and any individuals who will be helping you with transportation or supervision of the students.

4. Advise the students (and perhaps parents as well) of suitable clothing for the trip.

5. If the students are to make notes, make sure that they take writing materials with them.

6. If necessary, discuss with the class suitable conduct and standards of courtesy that should be observed during the field trip. Allow the students themselves to suggest these.

7. If the group is large, you may wish to divide the students into "teams." Each team could have a leader. The leader might be an older student, a parent, or another teacher who has agreed to help you.

8. If desired, each "team" might be given a specific assignment with regard to things to watch for or information to be gathered during the trip.

9. Don't plan for the students to see too much in one trip. Make sure that you are not rushing them through the trip. This is especially important with younger students.

10. During the field trip, encourage the students to *observe* carefully and accurately.

11. If brochures or maps or other explanatory materials are available at the place you are visiting, obtain some for later classroom use.

12. Classroom follow-up can take many forms. There should almost certainly be a classroom discussion of the experience and how well it achieved the predetermined purpose. Other possible forms of follow-up would include: oral and/or written reports, field-trip booklets or diaries, posters, murals, more comprehensive, illustrated class projects, and repeat visits to investigate aspects the students feel they did not see thoroughly enough on the first visit.

Certain cautions are in order with respect to having students make field trips into natural environments. Such environments can be much more easily damaged than we often realize, as pointed out in the following excerpt from *Nuffield Junior Science, Teacher's Guide 1*, published for the Nuffield Foundation by William Collins Sons & Co. Ltd., London, 1967, p. 268.

"Apart from the dangers created by collecting there is the possibility of damage from thirty to forty pairs of feet. This is generally less harmful to plant life than animal.

"Recently, a study was made of the effect of a group of twenty people walking through a stream with a rocky bottom. The disturbance of the stones by feet resulted in a large haul of animals, mainly stonefly and mayfly nymphs, being caught in nets placed further down the stream. Examination of these disturbed areas showed that they had a reduced population of animals compared to undisturbed areas.

"Disturbance of stones in terrestrial habitats can result in the destruction of microhabitats exposing the animals to dangers of desiccation or predation. All stones turned over on the sea shore, land, ponds, or streams should be replaced as nearly as possible in their original position.

"Damage to vegetation may be slight, but for a small group of flowering plants it may mean that flowering cannot take place that season, so there will be a loss of seed this year. Clearly, if this were repeated annually some plants in the area would eventually be destroyed.

"Even slight damage to vegetation may be sufficient to indicate the presence of a nesting bird to a natural predator or suggest its presence to other humans. When we observe nesting birds we must take care not to expose the nest in any way. We must strike a balance between the need to observe and the risks of desertion and predation.

"Occasionally, the interest of the [students] may, as in a case we know of, when a group of ten-year-old boys wanted to band birds, have to be opposed because they would contravene the laws of the land. It is illegal to capture a bird for observation or banding unless the catcher has a licence to do so. Any such work would have to be done by a licensed specialist who could be called upon to help or take the [students] on a visit to a local bird observatory.

"One bird observatory run by a group of amateur ornithologists arranges transport facilities for visiting school parties, and its members demonstrate the varying techniques used. They are most helpful to parties wishing to do general field work in the area surrounding the observatory, but do not allow visits to the rocky shore and sand dune areas during the breeding season of ground nesting birds. The use of local experts in this way can be of great value both to the teacher and the class. Information about the distribution of rare plants and animals and the areas in which they occur is valuable in deciding suitable areas in which the pupils can work. Clearly such areas should be avoided for general field work."

Review and Evaluation

The progression and continuity of the SEEDS program follow a spiral pattern. It is often impossible to present an important concept fully when first introduced at the primary levels because of the relative immaturity of the students. However, in the SEEDS program, that same concept is presented again within the level, and also from level to level. Each time the concept is presented, the context is somewhat different and the meaning is more completely developed: such an approach helps the students gain an increasing understanding of a core of essential ideas. The use of the spiral approach also constitutes a built-in review mechanism within the program.

In spite of the continual recycling of concepts, you may find on occasion that certain facts and ideas need to be reviewed or retaught.

Evaluation of student learning can take several forms. Particularly applicable to the SEEDS program is the observation of pupil behavior with reference to specific stated objectives.

Since the learning objectives for each section of the SEEDS program are specifically stated at the beginning of that section in the Teacher's Guide or Teacher's Resource Book, they provide a basis for evaluation. Other important educational goals may be found in the discussion of cognitive and attitudinal objectives. Each student should be observed over a period of time, and those observations should be recorded in writing periodically. Such accumulated written observations can serve as a valuable basis upon which to form an opinion about individual pupil learning.

One should be careful to keep individual differences in mind. What might represent real progress for one student might be less important for another.

Also, it is not enough to be satisfied with mere verbal performance. The emergence of new behaviors in the classroom also indicates that learning has taken place. The following are some examples of acquired behaviors:

1. Showing originality and resourcefulness in research.

2. Finding solutions through reading.

3. Participating in experimentation.

4. Engaging in investigative activities on one's own initiative.

5. Beginning to expect and look for predictability and order in relation to natural phenomena.

6. Distinguishing fact from fancy.

7. Questioning and evaluating sources of information.

8. Withholding judgment until sufficient evidence is available.

9. Demonstrating the ability to be either a leader or a follower, depending on the situation.

10. Showing by actions that one understands and sympathizes with the feelings of other people.

Student questions in the Student Book and in the Teacher's Resource Book are of several different types, concentrating not only on subject matter but also on thinking skills such as identifying reasons, understanding processes, and making comparisons. These questions provide another instrument for assessing the day-to-day acquisition of learning of the students.

Materials

Materials Found Within the Program Itself

As stated earlier, the SEEDS program provides a full range of materials for each post-elementary level.

1. A comprehensive Teacher's Resource Book with Professional Reference Guide.

2. A Student Book that has been designed to stimulate the students' curiosity about energy and the world around them.

3. A series of reproducible Exercise Sheets for additional written work (found at the end of the Teacher's Resource Book).

Complete and specific instructions for the use of the materials will be found as one progresses through the numbered chapters in the Teacher's Resource Book.

The use of the Student Book, particularly, is quite flexible. Sometimes it is used to introduce a concept. Sometimes it is used as a focus for group work. At other times the Student Book is used to summarize or review what has gone before.

The students are not to write in their Student Books. Students are encouraged to keep an activity notebook in which to record their observations and conclusions. The reproducible Exercise Sheets for each level provide for additional reinforcement of and response to what has been learned.

The Professional Reference Guide provides helpful teaching strategies, as well as background information about the program, and the kind of pedagogy it is based on.

Concrete Materials to Accompany the Program

A recent survey of science teachers revealed that one of the greatest problems they experienced was the difficulty of obtaining materials for scientific experiments and demonstrations. The materials required for experiments and demonstrations in the SEEDS program have been deliberately kept very simple. For the most part, at the upper levels, they are the kinds of things that can be easily found in the average science classroom.

In addition to the materials directly required for experiments and demonstrations, the teacher of the SEEDS program would be well advised to assemble as many other related "real things" as possible. These might include: classroom plants of different kinds, a rock collection, a shell collection, a leaf collection, samples of various kinds of wood, samples of fossil fuels, objects made from fossil fuels, a terrarium, an aquarium, and so on. Of course, many science classrooms already have an abundance of this kind of material.

Some of the many advantages of realia in the classroom are that they:

1. Introduce a variety of stimuli, encouraging the students to use all of their senses—seeing, hearing, touching, tasting, and smelling.
2. Increase and sustain the students' attention.
3. Bring into the classroom events and phenomena that would otherwise remain remote in place or time.
4. Illustrate applications of abstract concepts, and increase their meaningfulness for the students.
5. Can promote a spirit of cooperation and develop a sense of responsibility in the students especially if their help is enlisted in assembling the objects and caring for them.

Printed Materials as a Resource for the SEEDS Program

A wide selection of books, pamphlets, pictures, and other printed reference materials related to energy and the environment should be made easily available to the students if at all possible. A comprehensive collection of such material will help to meet the special needs of individuals. For example, a student might have poor reading ability, but be very much interested in finding out more about coal mining. An "easy" library book on the subject can meet this special need. Another student might be putting together a report on a current energy issue. A readily available and up-to-date collection of newspaper clippings can be of great help to this student.

A wide selection of materials allows students to work independently or in small groups, either to complete projects suggested with the SEEDS program or perhaps to carry out their own investigations on matters of particular regional interest. An abundance of available material also encourages students to maintain the valuable habit of consulting a variety of sources.

Printed materials that would be particularly useful to the students working on the upper levels of the SEEDS program include:

1. One or more sets of encyclopedias, preferably well-illustrated.
2. Nonfiction, science-oriented books written for the general public.
3. Atlases and maps.
4. Dictionaries.
5. National almanacs; world almanacs.
6. Leaflets, pamphlets, bulletins, brochures, calendars, charts, posters—often found as free or inexpensive materials from museums, historical societies, conservation organizations, commercial companies and so on.
7. Pictures, photographs, postcards.
8. Magazines (some adult-level technical magazines may also be suitable as reference for interested students).

9. Relevant newspaper clippings.

10. Locally produced materials—reports on use of energy in your community, guides to wildlife identification in local parks, local histories, and so on.

If you have access to a large central library, you might take out a number of books relating to particular subjects in the SEEDS program. Many communities also have travelling libraries. With advance planning, a selection of appropriate books could be on hand when needed. Sometimes books and other materials can be borrowed from Departments of Education.

A teacher who develops a "collector's eye" can, in the course of everyday life, amass an amazing amount of free and inexpensive printed material suitable for use in the classroom. Students can assist in finding and organizing such material. For example, they could write letters requesting free government publications, booklets published by various industries, and so on. With teacher guidance, they could also develop an efficient filing system for the collected material.

The following are a few suggestions for the use of supplementary printed materials with the students.

1. Select books and other materials with care. Try to make sure that they give accurate information. If discrepancies arise between books, take advantage of the situation to point out that it is wise to evaluate sources carefully and consult a variety of sources whenever possible.

2. Whenever possible, use reference reading materials after the students have had firsthand experience or have read and discussed the material in the Student Book. The reference materials will help them pursue special interests or answer new questions raised in their minds.

3. Generally, have the students read with specific purposes in mind. Help them to be selective, recording and reporting only the information that is appropriate to their particular investigation or project.

4. Be sure students know how to use tables of contents, indexes, glossaries, and other reference tools, properly.

Choosing Supplementary Audio-visual Materials

The SEEDS program offers a filmstrip for each elementary level, and also concept framework filmstrips covering Levels 1–3 and Levels 4–6. At the post-elementary levels, other useful filmstrips, as well as slide presentations and motion pictures, are available from a variety of sources. However, these do need to be carefully chosen if they are to achieve the desired objectives. They should be appropriate to the ages of the students. Any supplementary audio-visuals should also be accurate and should present sufficient data for the development of concepts. There should be a balanced presentation of data and viewpoints. One should watch this particularly with audio-visuals produced by special-interest groups such as commercial companies or advocates of very different alternative lifestyles.

If you have specialized knowledge in a particular area or access to special equipment or settings, you may wish to consider making some audio-visuals of your own. For example, if you are able to visit a site where oil sands are being mined, you might wish to make a slide presentation or filmstrip of the process. Other teachers in your school may have personal slide collections or movie films that could prove useful. Students themselves may be able to participate in photography and film-making.

Using Audio-visual Materials

The following are some general guidelines for the use of filmstrips and other audio-visuals with the SEEDS program:

1. Always store filmstrips at room temperature. If filmstrips are used when they are hot, they will stretch. If they are cold, they will become brittle and break.

2. Always preview the audio-visual before using it with the class. You might do this alone, with other teachers, or perhaps with a small committee of students. Plan how the audio-visual will be used, referring to the film guide if there is one.

3. Prepare the class. Discuss with them the reasons for seeing the film. Give them some main points to watch for, helping the students to separate the important from the unimportant. Present any difficult vocabulary used in the film if you feel this is necessary. List any questions that the students would like to have answered through the viewing of the film.

4. After the students have seen the film, discuss it with them to see what they have learned from it. Discuss whether the film answered the questions that the students posed beforehand.

5. Do not expect too much from one showing of a film. At least two showings of a particular film are often advisable. You may wish to show the film without the sound the second time. This will allow you and the students to discuss the film as it progresses. It can also be a technique for evaluating learning if you ask questions or have the students supply the commentary.

6. In order to involve the students even more, you might like to have them record, in groups, their own version of the audio portion of filmstrips.

7. Sometimes a follow-up activity may be appropriate. This might take the form of a written or oral report, creative writing, research, preparation of pictures or charts, role-playing, or dramatization.

Notes

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